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This beryl and schorl specimen is a magnificent example of the minerals coming from the Shigar Valley of Pakistan. (Photo by Jeff Scovil/Herb Obodda specimen)

Miller Magazines, Inc.

Rock & Gem (ISSN 0048-8453, USPS 486-290) is published monthly by Miller Magazines, Inc., 290 Maple Ct., Ste. 232, Ventura, California 93003-3517, telephone (805) 644-3824. Periodicals postage paid at Ventura, CA 93006, and additional mailing offices. Single-copy price $4.99. Subscription in U.S.A. and possessions: 1 year (12 issues) for $24.00; 2 years for $42.00; 3 years for $54.00. Add $16.00 per year postage for Canada and all other foreign countries. Submission of articles and photos by our readers is welcome, but we can accept no responsibility for loss or damage to unsolicited editorial contributions.

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Printed in U.S.A.

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Rock & Gem,
P.O. Box 469113, Escondido, CA 92046-9113
or RockAndGem@pcspublink.com

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WAR and GEMS

Danger Surrounds the Mineral Treasures of Pakistan and Afghanistan

Story by Kiera Tara O'Brien /
Photos by Bob Jones

On the far western side of the Himalaya Mountains lies the diverse region of Central Asia, largely known today for highly publicized conflicts and natural disasters in the two modern states of Pakistan and Afghanistan. In this land-locked region, decades of armed conflict and the slow development of social and economic infrastructure have previously hindered the creation of a larger and more stable gem industry.

Recent business reports by the BBC and CNN, however, suggest that Pakistan's economy is on the verge of a breakthrough and is looking like the next big opportunity. Neighboring Afghanistan is more than a few years behind, but hopes are high for the coming decade. Determination, education, and a killer natural product might just translate into the growth of a gem business that could pull the whole region out of its serious economic troubles.

WHERE RANGE ROVERS FEAR TO TREAD

The Hindu Kush mountain range, joining the western end of the Himalayas and stretching from central Afghanistan into northern Pakistan, is littered with remote gem-mining localities, some of which are nearly inaccessible due to the harsh climate and landscape. With peaks reaching up to 19,500 feet (6,000 meters) and steep river valleys cutting through the rugged landscape, it is no wonder that many places can only be reached on foot and with pack animals.

Historically, these isolated gem-producing regions have been a source of wealth and grandeur for the nomadic kings of Central Asia and the maharajahs of the Indian subcontinent. Artifacts and relics excavated by early archaeologists and treasure hunters, such as the many bejeweled objects of the Gandhara and Indus civilizations, are poignant examples of the wealth and power of ancient rulers who accessed these natural resources.

Aquamarine occurs in almost every locality in the northern areas of Pakistan. This dramatic piece comes from Nagar, Hunza.

Columnar kunzites in stunning violet shades are an example of the high-quality specimens Afghanistan has to offer.

A brilliant aqua specimen of beryl from Nagar, Hunza, testifies to the quality of Pakistani minerals.

A beautiful mix of colors is created when lapis lazuli forms with mica crystals from Sar-e-sang in Badakhshan, Afghanistan.

The modern state of Pakistan came into existence in 1947 after the British partitioned off the Indian subcontinent. In the half-century following its founding, Pakistan has given little attention to exploiting and developing its potential gem industry, having been preoccupied with political and militaristic tensions with India. In the last decade, however, a new interest in gems and minerals has seen Pakistan take the first steps in building up its infrastructure and market. Not only have there been efforts to encourage exploration and mining in the region, but the traditional gem-trading towns of Peshawar and Quetta are looking to become major centers of the gem business.

In the northern areas of Pakistan, where the famous Hindu Kush, Himalaya and Karakorum mountain ranges converge, a wide array of minerals have been discovered, including ruby, emerald, aquamarine, topaz, epidote, peridot, amethyst, morganite, zoisite, spinel, and tourmaline. A few major mining areas are found in the Northwest Frontier Province and the Northern Area Districts. Peridot is common in Kohistan in the Hazara division, while emerald occurs with various types of quartz at Swat in the Malakand division.

Tourmaline in rich colors comes from the Diamar and Gilgit districts in the Northern Areas, along with lovely golden and white versions of topaz. Aquamarine occurs in almost every locality in this area, but the emerald-colored tourmaline and rubies, many of which decorated the idols and objects of the ancient Indian rulers, are what really stand out.

BUILDING THE FUTURE, ONE SHOW AT A TIME

Despite being a source of world-renowned—and top-quality!—specimens, Pakistan has only started to market itself as a major player in the gem world. Last year, the 12th Pakistan Gems and Minerals Show was held in Peshawar, near the Afghan border. Organized by the Export Promotion Bureau in a city hotel, the show featured a full range of specimens from the region, including peridot, topaz, morganite, and sapphires.

Around 30 local gem companies cooperated to produce an exhibit of Pakistani minerals with the hope of promoting Pakistan as an emerging gem market for the few foreign buyers from France, India, Brazil, and Thailand that attended. Peshawar has always benefited from the flow of smuggled Afghani gems into its markets and, in another decade, may be an important international destination for rockhounds and gem lovers. In fact, almost all Afghani specimens make the long, dangerous journey through militia-controlled territory to Peshawar before arriving in a collector's or lapidary's hands!

In the past, gems have been transferred to expert lapidary centers in Thailand, Sri Lanka, and Germany before making it onto a broader world market. The establishment of the Gem and Gemological Institute of Pakistan, however, has seen more than 1,000 students complete training in gemology and lapidary techniques, a bright prospect for the more efficient and more affordable arrival of Pakistani gems on the market. It is also a reflection of a growing realization in Pakistan that government support is necessary if the country is to tap its enormous potential mineral wealth.

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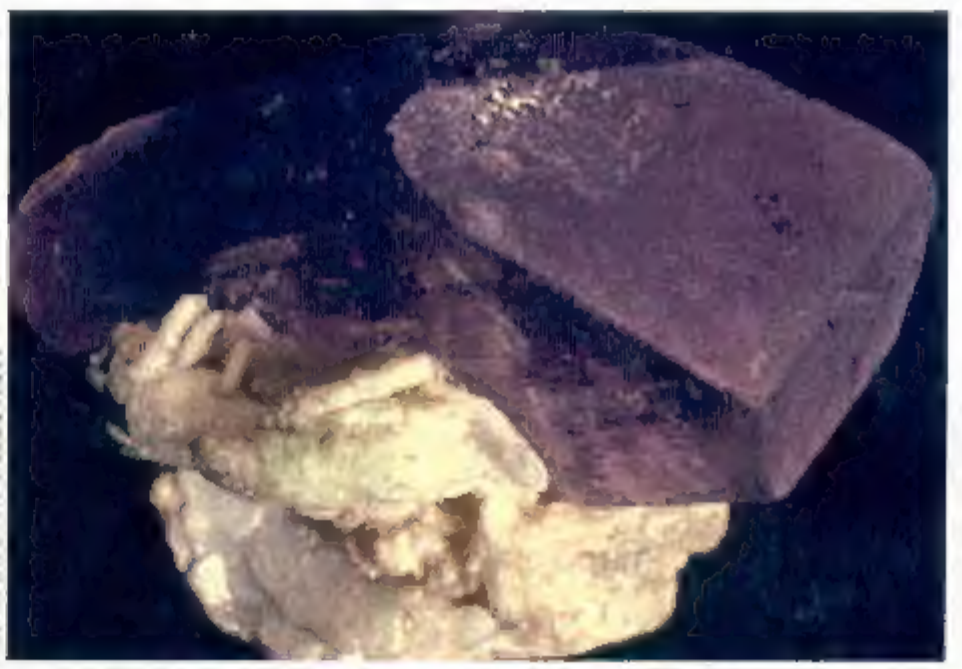
Beautifully cut gems like this topaz from Dassu in the Braldu Valley are valuable assets in the growing Pakistani economy.



BILL LARSON COLLECTION

A rare matrix specimen from Afghanistan's pegmatites, this wedge-shaped violet kunzite is in situ with tourmaline and albite.

War and Gems *from page 13*

A few other events in the last few years have seen Pakistani mining and distribution infrastructure take some tentative steps forward. In July 2004, the International Colored Gemstone Association appointed a Pakistani mineral dealer and member of Pakistan's Gems and Jewelry Strategy Working Group, Ambarine Bukharey, as one of its newest ambassadors. The Strategy Working Group to which Bukharey belongs is part of a greater effort to increase gem education and co-operation in Pakistan, which is hoping to attract joint venture projects in exploration and mining to the region. Dealer groups are hoping for increased funding from the government to establish gem exchange centers with laboratories and offices for encouraging export infrastructure. If all this works out according to plan, collectors and gem lovers can look forward to easier access to quality Pakistani minerals straight from the source.

AFGHANISTAN: A LOST CAUSE?

On the other end of the Hindu Kush mountain range, Afghanistan is another underexploited gem of Central Asia. Geologically, Afghanistan is a collection of crustal plates that jammed together around 75 million to 45 million years ago, forming the Himalaya range. The most famous Afghani gems, spinel and lapis lazuli, have been mined with much the same techniques since ancient times, with the exception of the current enthusiasm for dynamite.

Marco Polo once mentioned Afghanistan as the place with "the mountains where the finest azure in the world is found." Tourmaline, aquamarine, emeralds, morganite, kunzite, ruby, and pink sapphire are some of the more common specimens that are smuggled into Peshawar these days.

As in Pakistan, it is the northern part of Afghanistan, to the north and east of the capital of Kabul, that has yielded the most material so far. The Panshjer valley is known for emeralds and the Sorobi district is producing limited amounts of quality rubies, while tourmaline, kunzite and aquamarine are primarily found in the pegmatite-rich localities of the Nuristan region. Some particularly striking specimens from the pegmatite areas are brilliant violet varieties of kunzite in columnar and wedge shapes.

Located to the east of the emerald-producing Panshjer valley, Nuristan has become a major source of green, blue and pink tourmaline in large quantities. Tourmaline has been mined there since the 1970s when the area was first explored by Soviet geologists. A few other major minerals coming out of the same area are quartz, beryl, microline, albite, and muscovite. The tourmaline and beryl is notable for its size (around 15 centimeters long), color diversity, and finely shaped crystals, which are generally free of fractures and problems.

Along with the last empress of China, I love a nice specimen of subtly shaded pink tourmaline, such as that which came out of Southern California. But it is the strong greens and blues that are considered the best (most salable) finds. Along with the other pegmatite gems (kunzite and aquamarine) and emeralds, tourmaline is potentially Afghanistan's best product.

Directly north of Kabul, the Panshjer valley has been a source of emeralds for ages; in recent times, it has been controlled by the "Lion of Panshjer," a regional war hero (or war lord, depending on your point of view). Panshjer emeralds typically appear with very pale interiors and rich, dark exteriors. Only in the last 30 years have commercial amounts of emerald become available. These specimens are commonly associated with pyrite, a good indicator for miners that an emerald pocket might be found along a particular vein.

Similar to Colombian emeralds, the Panshjer emeralds are an extremely dark green and have actually been incorrectly labeled as Colombian in some instances. Some emerald experts even think these Afghan minerals are often of higher quality and finer color than their Colombian brethren—although that is clearly a matter of opinion!

The Panshjer valley is situated at the meeting point of two crustal plates: the Asian plate and the Cimmeria. The emerald deposits are located to the southeast of this fault line on the eastern side of the valley. The west is thus far void of emeralds, a situation that might be explained if more detailed geological studies can someday be undertaken in the area. On the eastern side, miners find the emerald pockets in quartz and ankerite veins running through a limestone base. Varying in size, these specimens can range up to about 130 carats.

The Mikeni and Darkhenji mines are thought to produce the best emeralds of the valley, but with almost 100 current mining sites, there are plenty of other rivals for the prize position. These mines, which are more like dozens of sporadically placed pits and tunnels than what we in the United States might

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War and Gems *from page 14*

consider a mine to look like, are located at high altitudes, roughly between 7,000 and 14,000 feet. Explosives, hand tools, and power drills are used in a rather unorganized manner to dislodge the emeralds, often destroying some in the process, and mules are the best source of transport in the area. It is incredibly hard to reach these rugged mountainous areas and, of course, it is even harder to get the minerals out of the area and across the border into Pakistan for sale.

Making the border crossing is a challenge in itself. Renegade Taliban groups, tribal militias, and scattered explosive devices are all serious impediments along the way. Were the situation to clear up in the future, emeralds could certainly be Afghanistan's ticket out of economic troubles. In the past, Afghanistan's gems, particularly rubies, emeralds, and lapis lazuli, have been used to fund the purchase of arms, first by the Mujahaddin in the resistance against Soviet invaders, and later by the Northern Alliance.

If Afghanistan is going to take advantage of this natural resource, hopefully for funding social and economic reconstruction efforts rather than munitions programs, then serious advances in mining technology are needed. The antiquarian form of mining used nowadays not only destroys a lot of potentially salable specimens, but only really taps the surface of the quantities of minerals available. New gem deposits have already been located, but there is no mining infrastructure available to reach these deep sources.

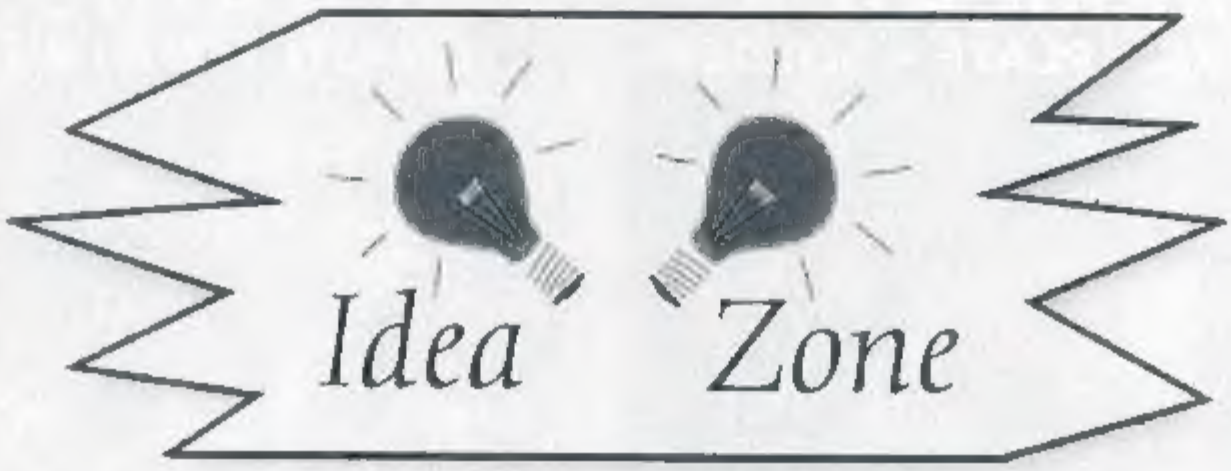
It is clear that Afghanistan has a wealth of high-quality specimens to offer the world markets. The 1980s saw the most Afghani material reaching centers in Thailand, Europe, and the United States, but the current conditions are hardly conducive to gem production. At the moment, the new Afghani government is attempting to assert some control over mining, but without the force to ensure regulations, it has largely been ignored and the old-style dynamite and pick mining has continued.

Pakistan is really starting to take clear steps forward to develop and consolidate its gem and mineral industry, with the result that a huge array of prize specimens is starting to reach the market faster. Meanwhile, Afghanistan is, understandably, lagging behind its blooming neighbor. Lacking stable governmental and social and economic infrastructure, local miners simply continue their tradition of rustic mining and traveling the dangerous route to Peshawar. This is the only way a collector can hope to land one of the beautiful specimens from Afghanistan.

SHOP TALK

by William A. Kappele

Idea Zone



Every now and then, I get the bug to try and find new ways to put to use the fruits—or, as they sometimes turn out, vegetables—of my lapidary labors. It seems only fair that I use this column to bore you with some of them.

Once, back when the world and I were both young and the rock bug had not yet bitten me, I remodeled our kitchen on a very tight budget. One of the things I did was to make my own cabinet door pulls from a simple piece of walnut about 3 inches by 1½ inches by ¾ inch. I cut a bevel on the back edges for finger pulls and a groove about ⅛ inch deep on the face. In the groove, I glued some mosaic tiles like the ones I used to cover the countertops.

Today, I would use some thin slabs of my favorite stones. In the kitchen, I would use jasper or agate. In the shop, I would use leaverite. For fine furniture like a media center, I would use something like malachite or whatever I could afford. For more informal areas like the shop or laundry room, just large tumbled stones with screws epoxied on the backs would work great. You could also use ready-made knobs from the home center and cover them with crushed stones in resin. There are lots of ways to get rid of our rocks. Turn your imagination loose.

Along the same lines, I once built a Baja Bug out of a Volkswagen. The dash was Carpathian elm burl and the inserts in all the knobs on the dash were malachite. This was an easy one, since the folks at Volkswagen made their knobs of a soft rubber with plastic inserts that defined the knobs' use (wipers, choke, etc.). It was a simple task to pop out the plastic and insert the round malachite cabs. Try it on your Ferrari—although you might want to use fire agate or gold nuggets.

If you don't want to touch your Ferrari, how about making a nice cheese board? A large freeform slab would be nice, but you can go geometric, or even use smaller slabs and do a mosaic pattern. You can get as fancy as you want by epoxying the slab to a teak board or just gluing some thin cork on the back. It's all up to you. Along the same line, don't overlook trivets or coasters. I'll bet Aunt Freda would appreciate it if Uncle Fred had a nice coaster to set his diet cola on and save the antique end table.

Craft Supplies USA has a free catalog chock full of stuff that works perfectly with cabs and slabs. You can find them on the Internet at www.woodturnerscatalog.com.

If you are a golfer, or know one, you can find gold-plated ball markers and divot repair tools that take a small, round cab. They make great gifts. There are also money clips, round pill boxes, compacts, and gold-plated bookmarks, all of which are set up for round cabs of various sizes.

Finally, don't forget the humble refrigerator magnet. Just glue your cab or slab to a small magnet and you have a nice thank-you gift or something with which to stick yet another photo or clipping to the ice box.

Happy crafting!

Please feel free to contact me if you have a suggestion or comment about this or any of my Shop Talk columns. My e-mail is quappelle@cox.net, or write to me at 25231 Pericia Dr., Mission Viejo, CA 92691.

THE FRUGAL COLLECTOR

THE SILICATES

Part III:
Vesuvianite, Garnet, Rhondonite, Hemimorphite, Kyanite, and Staurolite

Story and Photos by Bob Jones

When the semimetal silicon joins with oxygen to form a silicate radical, the resulting molecule always consists of one atom of silicon and four atoms of oxygen. They join in the shape of a tetrahedron, but because some of oxygen's electrons are still exposed or unattached, the silicate radical can join with atoms of almost untold numbers of other elements. This explains in part why there are so many silicate species and why so many of them are chemically complex.

Tourmaline, for instance, can hold no fewer than 13 different elements, with more than 50 atoms in its molecular structure. In comparison, the relatively simple carbonate calcite's molecule consists of one calcium atom, one carbon atom, and two oxygen atoms. The zeolites, all of which are silicates, can also be pretty complex, as can any number of uncommon and rare silicates.

As the Periodic Table of Chemical Elements was evolving, scientists realized many elements like gold, silver, iron, and copper had metallic properties. We discovered all these metallic elements have three or fewer electrons in their outermost electron shell, the part of the atom that is usually involved in chemical reactions.

A smaller number of elements that do not have metallic properties have five or more electrons in their outer electron shells. Chemical compounds, like minerals, are formed when one or more metallic elements combine with one or more nonmetallic elements. They usually do this by sharing electrons.

A fine cluster of superb rhodonite blades came from the Chieruco Mine in Huanaco, Peru.

An even smaller group of elements has the stable number of eight electrons in their outer shells. These are what we call the noble, or inert, gases, which will not react with anything under normal circumstances. This group is headed by the inert gas helium. It has two electrons in its outer shell. Hydrogen, on the other hand, has one electron in its outer shell and can act like a metal or nonmetal in a reaction.

Finally, another group of elements has four electrons in their outer shells. We find silicon in this group, along with lead, tin, germanium, and carbon. Because these group members have more than three but fewer than five electrons in their outer shells, they have some of the properties of a metal and some properties of a nonmetal. Hence, we call this group semimetals, or metalloids.

The four-electron elements have the unusual ability to join with some metal elements *or* with some nonmetal elements. That makes for rather complex chemistry! Those four outer-shell electrons partly explain why silicon is so often a part of chemical reactions and of so many silicate minerals.

Sometimes, the hemimorphite from Santa Eulalia, Chihuahua, Mexico, occurs on snow-white calcite rhombs.

Kyanite from Brazil ranks among some of the finest blue kyanite found anywhere.

The Jeffrey Mine in Asbestos, Quebec, is world-famous for superb violet-colored vesuvianites.

Vesuvianite is an excellent example of how complex a silicate can get. It is a hydroxyl calcium, aluminum, magnesium, iron silicate with additional oxygen and fluorine. One vesuvianite molecule can be made up of more than 150 atoms centered around the silicate radical. No wonder scientists were dizzy trying to figure out this mineral when it was found centuries ago. They couldn't even settle on a name for the mineral. Its first name, "idocrase," was formed from Greek words that refer to the many external crystal forms the mineral can adopt. Finally, when the mineral was found in ancient lavas from Mount Somme, near Vesuvius, it was named "vesuvianite."

Vesuvianite can come in a variety of colors, and its crystals range from opaque to transparent and gemmy. The opaque varieties tend to be yellow, yellow-brown, or dark brown. Most gemmy crystals are colored grass green to yellow to delicate violet.

Though vesuvianite is chemically complex, it is not rare, occurring in literally hundreds of localities, of which only a few produce exciting collector specimens. It forms in a partly metamorphosed limestone and in skarns that result from metamorphic action. It is also found in nepheline syenites, a granitelike rock with only minimal quartz content.

The finest vesuvianites in this country come from the Jeffrey Mine in Eden Mills, Vermont, an open cast asbestos mine that is no longer operating. Collectors have been able to get in and work mineralized veins in which superb, gemmy vesuvianite and attractive, cinnamon-colored grossular garnets are found. The garnets are among the nicest found in America.

The colors of Eden Mills vesuvianite range from green to yellow to a lovely and delicate violet. Crystals are prismatic, slender prisms to 4 inches long. They are striated and often color zoned. They are usually gemmy and are the most attractive vesuvianites I've ever seen!

Another Vermont locality, the Belvidere Mount Quarry near Lowell, has produced similar crystals, but in lesser amounts.

North of the Eden Mills deposit, in Canada, are the Thetford mines of Megantic County. This heavily worked deposit produced large numbers of cinnamon garnets and a number of fine vesuvianites.

The cause of color in some vesuvianites has yet to be decided, but the Eden Mills beauties get their green color from chromium ions, while the violet crystals hold a trace of manganese. Specimens from this locality are not common these days, and because they are so attractive, they are eagerly sought.

The classic locality for vesuvianite in America is Minot, Maine, near the town of Sanford. This is a metamorphic deposit rich in quartz in which brown, blocky vesuvianites have been found associated with lovely, lighter brown, opaque grossulars. The Minot vesuvianites have high luster and the typical square cross section; you can usually see slightly rounded or curving prism faces when you look down the length of the crystal. These give the square outline rounded corners. The Minot crystals average about an inch in length, but crystals to 8 inches have been mined here. The deposit may still be open to collecting, but it is very hard to work the narrow quartz veins in the limestone.

The famous Crestmore Quarry in Riverside, California, is another metamorphosed limestone deposit that has produced excellent, sharp vesuvianites. Formerly open to club-sponsored collecting, Crestmore is now closed to collectors.

Colorado boasts an interesting vesuvianite deposit that also produces massive lapis. The source is high on Italian Mountain in Gunnison County and is claimed, so private collecting is discouraged. Vesuvianites here are tabular.

In the benitoite locality area of San Benito County, California, fine vesuvianite and black andradite garnets occur in a gray matrix. The garnets are small and sharp, in typical dodecahedron form, and tend to be tightly clustered. The 1-inch vesuvianites are sharp and brown.

Around Lake Jaco in Morelos, Mexico, superb vesuvianite crystals have been found in abundance. The locality has been credited to the State of Chihuahua, but the scattered deposits are actually east of Lake Jaco, along the boundary between the states of Coahuila and Chihuahua.

continued on next page

The Mexican vesuvianites are opaque and mustard yellow-brown with a square cross section. They have a blocky form with very low pyramidal terminations. Crystals average about 1 inch or 2 inches long. Often, vesuvianites are found in small, blocky crystal clusters free of the white limestone rock in which they formed. Some crystals exceed an inch and many show interpenetrating twinning, as well as overgrowths. The number of crystals from this area is virtually limitless, as the rock outcrops containing them occur in several places.

The Lake Jaco locality is far better known for its amazing pale tan to bright green or pink garnets, which range from 1-inch simple dodecahedrons to baseball-size, perfect crystals. On rare occasions; these huge grossular garnets were found with one or more small, sharp, brown vesuvianites attached to or penetrating the garnet crystal. Grossular matrix specimens are virtually nonexistent. While the surface pickings are gone, the metamorphic limestone in which these beauties occur is still there and crystals appear widely scattered. The rock is very hard and difficult to work, so collecting efforts have been minimal.

Much more recently, a new locality for garnet and vesuvianite has been found east of Lake Jaco in the Sierra de la Cruz Mountains. These mountains actually form a hogback boundary between Chihuahua and Coahuila states. On the eastern slopes of the Sierra de la Cruz, a considerable distance from any roads, is a deposit far better known for wonderful, red grossular garnets, though both garnets and vesuvianites occur there abundantly.

The red grossulars get their wonderful color due to included manganese. They are generally an inch or so across, sometimes smaller, seldom larger. Some show interpenetrating clusters, but most occur as single textbook crystals in a white siliceous limestone. They are perfect dodecahedrons intimately associated with small, square, mustard-colored vesuvianites to an inch or so in length. Both species are tightly locked in the siliceous limestone, which often requires plenty of hammering to break down.

A few of the Lake Jaco garnets I've seen are penetrated by small vesuvianite crystals, but in most cases the garnets and vesuvianites occur as singles or in small, distinct clusters.

Several sources in the Ala Valley of Italy have produced very fine, green, gemmy vesuvianite, but the specimens are almost never seen today. Other European localities include Sweden, Finland, Hungary, and the Swiss Alps. Vesuvianites have even been found in quantity as far east as the Ural Mountains. All these localities are old sources and the only crystals you'll see from them now are in museums and the occasional private collection.

Fortunately for today's collectors, China has come online as a source of vesuvianite. Large, brown-green crystals occur with lovely, orange-tan garnets that tend to be under an inch in size and completely cover the matrix they are on.

Another recent source is Pakistan, where prismatic dipyramidal crystals have been mined. The Zhole Valley, in nearby Baluchistan, is another source for fine vesuvianites. This deposit should continue to produce for some time.

Some of Mexico's finest white hemimorphites came from the El Potosi Mine in Chihuahua.

One of the more unusual vesuvianite sources in America is the Franklin-Sterling Hill zinc mines in northwest New Jersey. This area is world-famous for the great variety of species that have formed here. Now thought to be the result of ancient black smokers, these two deposits have produced huge quantities of fine minerals in great variety. Many Franklin-Sterling Hill minerals fluoresce under ultraviolet light.

The Franklin-Sterling Hill vesuvianite is an odd blue color, thanks to the chromophore chromium. It never occurs in crystal form, only as massive streaks and veins in the zinc-rich metamorphic calcite.

Rhodonite is named for its pink-red color. Chemically, it is a manganese, calcium silicate, usually with some iron. It's a very attractive mineral, forming in blocky crystals with a rectangular cross section. It can also be found in small, bladed crystals clustered in rosette form. These seldom reach an inch on an edge, usually a little more than ¼ inch high, but they are tightly packed and completely cover the specimen matrix.

The blocky crystals have flat prism faces that are seldom modified, though they are often slightly rounded. The prism faces are not smooth. The Franklin, New Jersey, crystals develop locked in calcite, so small depressions and notches on the rhodonite prism faces can be filled with the white calcite. The edges of crystals are usually rounded due to restricted growth. With a nearly flat termination, most rhodonite crystals are not at all complex.

The most appealing type of rhodonite is the gemmy, rich red prisms from Australia. Since rhodonite is a manganese mineral, you can expect to find it where that element is common, as in some hydrothermal deposits. It is also common as a massive material where sedimentary deposits rich in manganese have been altered. It can be mistaken for massive rhodochrosite, but rhodochrosite occurs in banded layers of varying shades, while rhodonite is quite homogeneous in both form and color.

As if to confuse the average collector, nature has created another massive red to pink mineral, bustamite. It resembles rhodonite and even occurs in the same deposits.

The world's leading source of massive rhodonite today is the Kalahari manganese fields, which also produce that lovely violet manganese mineral sugilite. Perhaps the area is better known among collectors for its marvelous rhodochrosite crystals and a host of other manganese minerals.

In the United States, the major source of rhodonite is the famous zinc and iron manganese deposit at Franklin, New Jersey. The other nearby zinc deposit, Sterling Hill, is not noted for the mineral. The Franklin rhodonite exhibits two different sets of visual properties: those assigned to rhodonite and those assigned to the now-discredited name "fowlerite." Still, that name will always be used in referring to some rhodonite from Franklin since the original fowlerite has a lighter color and occurs in distinct bladed form. It was misidentified around 1825 and named after Dr. Samuel Fowler, who played a significant role in the development of the deposit. The lighter color of such rhodonite is due to small percentages of included zinc.

Franklin rhodonite is bladed and tabular and can reach as much as 8 inches in length, though most crystals are 1 to 2 inches long. Some of the Franklin rhodonites are free-standing, but these

have, by and large, been exposed by removing the enclosing calcite. White calcite, willemite of varying colors, minor massive red zincite and, occasionally, black franklinite can be associated with the red to pink rhodonite.

These New Jersey deposits were all formed by hydrothermal action associated with hot water ejections on an ancient ocean floor. Today, we call these hot springs at crustal plate boundaries "black smokers," a term that describes the gushing clouds of water bearing huge quantities of dissolved minerals that darken the water intensely. The minerals precipitate out and pile up as a deposit on the ocean floor. Evidence suggests this hydrothermal action dissolves minerals from the surrounding rocks of the Earth's crust and concentrates them to create future ore deposits. It has been pretty well decided that Franklin and Sterling Hill are ancient black smoker deposits made accessible by crustal movement, tectonic action, and weathering.

The rhodonite from Franklin is typically pink to red in blocky triclinic crystals. The calcite embedded in its faces shows the two minerals formed simultaneously. That strongly suggests a relatively low temperature environment of formation.

Bustamite, a calcium manganese silicate, lacks iron, so it is a distinct species. It is outwardly very much like rhodonite and occurs at the same localities, which makes it difficult to identify the two, especially in massive form. What distinguishes them is that bustamite contains more calcium and little or no iron, and has a greater number of silicate molecules in its structure. To complicate matters, some scientists, including those in Russia, call specimens that are only manganese silicate rhodonite. If calcium is present, they call the mineral bustamite. This is misleading, as rhodonite does contain calcium.

The finest gemmy rhodonite known has come from Broken Hill, New South Wales, Australia. The crystals are usually found locked in massive, bright galena, which shows typical perfect cleavage. The crystals that form in galena can be fairly sharp, but are often rounded. They tend to be perhaps an inch or so long, but can be longer. The color is often a deep, rich red to red-pink, and the crystals range from translucent to nearly transparent. On rare occasions, the Broken Hill rhodonite is found in open spaces in gemmy, light-red to red, perfect triclinic crystals.

Broken Hill, like Franklin, has been closed to mining, and specimens from here are scarce. While Sterling Hill is still being explored on a very limited basis, it is not producing any rhodonite. This means specimens must surface from old collections rather from any mining activity.

While the manganese fields in South Africa have produced wonderful lapidary rhodonite, a number of localities in America have provided artists with gem rough. Small quantities of workable rhodonite have occurred in North Carolina, Oregon, Montana, and California. Several of the California deposits have yielded good material to diggers, but these are all played out as far as I know.

The deposit that has yielded the largest masses of rhodonite ever mined, Malyoye Sedelnikovo, is deep in the Ural Mountains near Sverdlovsk. This huge deposit of massive rhodonite is shot through with spider webs of contrasting black manganese minerals. It has been mined for well over 100 years as a major lapidary mineral source.

The localities described so far do not yield rhodonite in thin-bladed crystals that approach rosettes in form. These come from the Chuquicu Mine near Huanzala in the Huanuco district of Peru. Had they been found in the 1800s, they would have been called fowlerite! Superb groups of these lovely blades, all tightly packed on matrix, came to light in 1989. They were an instant hit with advanced collectors and were priced accordingly. Another source for this type of rhodonite is the Pachapaqui district of Peru. Since these mines continue to work, perhaps more of these pretty rhodonites will surface.

In stark contrast to red rhodonite is the hydroxyl hydrate zinc silicate hemimorphite, earlier called calamine. It occurs as discrete crystals, but is also abundant as botryoidal masses that are sometimes a lovely pale blue or green. It can easily be confused with smithsonite which occurs in the same form and color range. Smithsonite is a zinc carbonate.

Hemimorphite is prismatic when crystallized, often occurring in colorless to snow-white crystals ranging from 1 to 4 inches long. When crystals are doubly terminated, the opposite terminations are different. This is what gave rise to the mineral's name based on "hemimorph," meaning "half-form." The mineral is common in at least two famous mines in Mexico, Mina Ojuela at Mapimi and Santa Eulalia, which region boasts several hemimorphite-producing mines.

continued on next page

Equally exciting is the richly colored blue botryoida hemimorphite now coming from China in huge plates and quantities. Sometimes, the blue masses are a foot or more across. Blue and even green botryoidal hemimorphite has been found in a number of places, including a couple of the mines in Durango, Mexico, and an older mine at Iglesais, Italy. Here in Arizona, the 79 Mine has produced lovely botryoidal green hemimorphite, along with small balls and undulating plates of blue material. Compared to the Chinese supply, these sources are fairly limited.

Certainly, one of the great deposits of hemimorphite in this country occurred at Sterling Hill, New Jersey, well known for its zinc minerals. In the 1850s, a major zinc deposit was unearthed there. Reported first as calamine, the hemimorphite was found in two massive surface deposits called the Noble and Passaic pits as white, thick, botryoidal crusts. Some of the calamine was 10 inches thick.

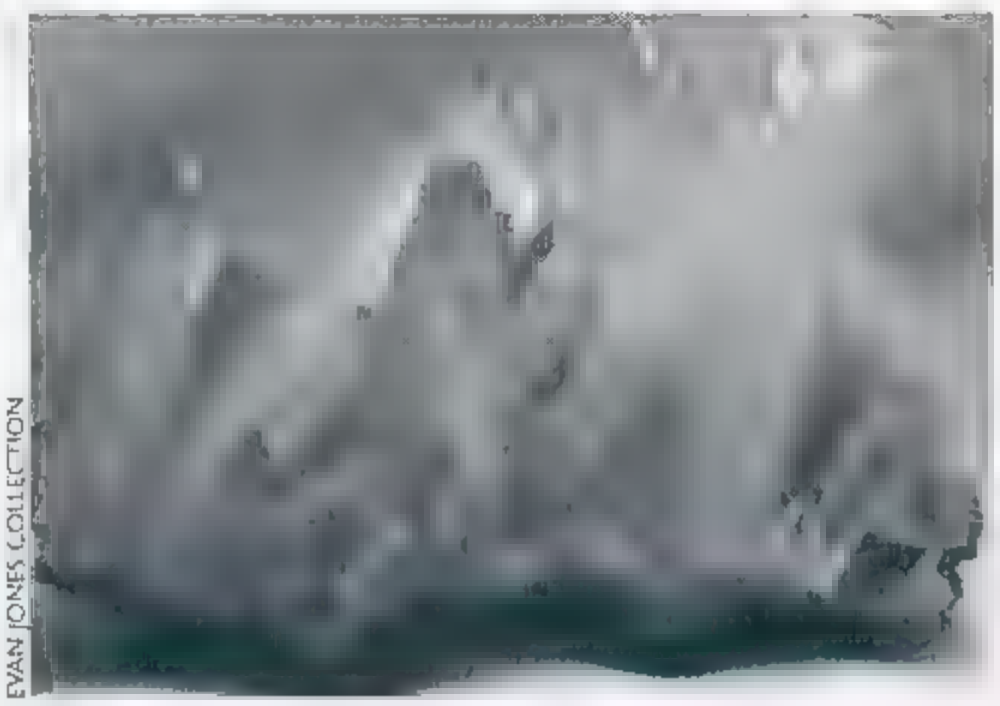
Plenty of specimens survived and are still occasionally seen for sale today. One reason is that they are not particularly attractive. The Sterling Hill hemimorphites are readily identifiable because of an odd surface habit they developed. Early miners called the mineral "maggot ore" or "worm ore" because its botryoidal surface is covered with curling, rounded humps.

Mexico is the leading source of hemimorphite these days, as American deposits like Leadville, Colorado, Granby, Missouri, Leadville, Colorado, and Eskhorn, Montana, are all played out. The Ojuela Mine in Mapimi, Durango, has produced some fine, small, white to colorless crystals of hemimorphite in the past. Many of the crystals are typical flat, bright, glassy white to colorless blades with swordlike terminations. Most are about an inch or so long. Less often, they can be several inches long. They occur on a brown to tan limonitic gossan matrix.

The primary Mexican sources, however, are the mines around Santa Eulalia, Chihuahua, including the Potos, and San Antonio mines. These mines produced hemimorphite in several forms. Small, crystallized masses with crystals sitting off in all directions are abundant. These often have no point of attachment, though it is not unusual to see small amounts of attached brown limonite within the crystal bundle. The crystals are not large, seldom reaching an inch. They are usually colorless, but may have a minor yellowish-tan hue because of iron oxide on and around the base of the crystals.

The better Santa Eulalia hemimorphites are snow-white crystals to several inches long. They occur in bundles of slightly diverging blades, so the crystal terminations are distinct, though the crystal base of a bundle is solid. The crystals are typically broadly flat and a fraction of an inch thick. They tend to be transparent at the terminations and cloudy white at the base.

The more exciting crystals have a rich dusting and inclusion of mahogany-red iron oxide, which has concentrated at the tips of the crystals. These crystals tend to be fatter and thicker than most.



EVAN JONES COLLECTION

The mines at Santa Eulalia, Mexico, yielded wonderful iron-stained hemimorphites.

The majority of the specimens from Santa Eulalia are pure white, lacking iron oxide inclusions. They are randomly attached to each other, sometimes penetrating, sometimes jutting off at an odd angle. Many show twinning. The supply in recent years has been excellent.

The Santo Nino Mine in Mexico produces an altogether different variety of hemimorphite, broad masses of botryoidal material. Most of it is blue, but it can range to pale pink, as well. Massive amounts of this material have been on the market as a result of intense mining.

Bisbee, Arizona, has produced a considerable quantity of hemimorphites that resemble the Santa Eulalia material. Since the mines at Bisbee have been closed for some time, these specimens have been dug by collectors able to get underground.

The 79 Mine, near Hayden, Arizona, has been much collected by amateurs. At first, diggers found superb wulfenite, paper-thin, bright orange wafers on black mottramite. The crystals were seldom more than a half-inch to an inch on an edge, but were exceedingly delicate and lovely. A few had a bright-red spot centered in the crystals due to a concentration of the chromophore chromium.

Eventually, the mine owners decided to give out a collecting contract. This closed the mine to amateur collectors, while professionals took over. Fine specimens came out, but because the mine incline and some stope areas were choked with mining debris, specimen mining was effectively discouraged.

Fine hemimorphites and other minerals from the 79 Mine are still available occasionally because intense collecting by amateurs had brought forth a good amount. Fine specimen mining effort has also been reasonably successful.

One of the classic sources for hemimorphite in Europe occurred on Sardinia near Montevecchio, which produced large masses of botryoidal hemimorphite ranging in color from yellow to yellow-green to blue-green.

Kyanite is a delightful mineral to study. It's very showy, with a rich blue to green color and long lathelike crystals. The better kyanite crystals are sharp and look like blue popsicles. The mineral is extremely hard on one face and very soft on another. When it forms in those long, flat crystals, it is even slightly flexible! You can take a single long crystal and flex it gently. That's most unusual for any crystal. When it does break, the broken ends are splintery, showing no cleavage plane.

Finally, kyanite is trichroic. If you look through the crystal from the front, side, and termination end, you'll see three slightly different colors. This property resembles tanzanite, another trichroic mineral. Kyanite is also gemmy at times and can be faceted. Its perfect cleavage presents a real challenge to the faceter. A faceted kyanite is easily mistaken for tanzanite because of the trichroic property.

Kyanite, formerly called cyanite, gets its name from the ancient Greek word for blue, but kyanite can be any one of several colors. It can be green, colorless, pink, gray, and even black with inclusions.

Another interesting property of kyanite is its trimorphism. This term is used to describe a group of three minerals all with the same chemical composition. Kyanite, sillimanite and andalusite are all aluminum silicate. They are made up

of two atoms of aluminum, one of silicon, and five of oxygen. The differences are in how these molecules of aluminum silicate arrange themselves. Kyanite's internal arrangement gives it a triclinic crystal form. The other two have orthorhombic arrangements.

Kyanite develops mainly in schists and gneisses, though it may also occur sparingly in pegmatites. In this country, fine kyanite occurs in two locations in North Carolina: Bakersville and Burnsville. The latter locality in Yancey County, yields short, gemmy crystals.

Blue kyanite is also found at Judd's Bridge in Litchfield County, Connecticut. This has long been a favorite collecting site for clubs.

The most unusual kyanite in this country is found in large quantities at Graves Mountain, Georgia. This deposit has been worked for decades for titanium. It also produces choice, lustrous, deep-red rutile crystals, some of America's best. The kyanite is most unusual, it developed in tightly packed, curving, iridescent crystalline masses. A light coating of an iron compound gives the kyanite an iridescent look, reflecting every color of the rainbow.

Some of the finest blue kyanites have come from Brazil, particularly from Quombo Capelina, Minas Gerais. Some of the blades here are a foot long, a rich blue color, and perfectly formed.

The big magnesite mine at Brumado, Bahia, Brazil, is also a good source of kyanite on a white magnesite matrix. The kyanite from Barra do Salinas, Coronel Murta, Sao Jose de Salina, Brazil, is as good as that from the other Brazilian sources.

The finest European locality, a classic, is at Pizzo Forna, Ticino Canton, Switzerland. Crystals tend to be blocky and occur with crystals of staurolite, another silicate. Staurolite is not a particularly showy or colorful mineral. Yet, it's one of those minerals that has great appeal to the general public because, in its very common twin form, it looks like a cross. Called "fairy crosses," such twins are often drilled and hung on a necklace.

Staurolite is found in most kyanite deposits and is common at the Roxbury, Connecticut, garnet locality. Superb, large twins have been mined for years in several places in Brittany, France, and in Portugal. Some of the French twins may be as much as a foot long.

Blue Ridge, Fannin County, Georgia, is probably the most prolific source for staurolite in America, though the mineral is also found in Massachusetts and New Hampshire.

FIELD TRIP

Cabbage Head Quartz

The Mechanicsburg collecting site, just west of Salem Church Road, is in a streambed near a playground, so the kids can play while mom or dad collects

Rosettes from Central Pennsylvania

Story and Photos by Robert Beard

Anyone who has driven the Pennsylvania Turnpike (U.S. Highway 70/76) across the state has experienced the striking changes in scenery and topography that come with crossing the major geologic provinces of the Appalachians. If you have never driven the Turnpike, look at any major highway map of Pennsylvania. The roads in the eastern and western parts of the state are not as constrained by topography, but as they approach the area west of Harrisburg, there is a pronounced northeast-southwest trend to the valleys, ridges and roads. The Turnpike looks relatively straight, but that is deceptive as it cuts through the ridges via a series of tunnels.

This section of Pennsylvania is known as the Valley and Ridge Province and it is perhaps the most striking feature of Eastern United States geology. This province forms the backbone of the Appalachian Mountains and extends all the way from Alabama into New York. It is principally a series of tightly folded Paleozoic carbonates, shales, siltstones, sandstones, and conglomerates.

Like all major geologic features in the country, it has had a profound effect on the development of the nation. Anthracite coal from the Valley and Ridge in northeastern Pennsylvania fueled industrial development in the East, and limestone and aggregate provided the flux for iron manufacturing and the construction of houses and roads. Perhaps most significantly, the Valley and Ridge forms one of the first major barriers to crossing the United States from east to west. One of the towns on the southeast side of the Valley and Ridge Province is Me-

The "cabbage head" quartz rosettes are found on the surface in weathered limestone.

Small pieces often have a distinct bull's-eye pattern that stands out well in the soil.

This egg-sized piece, found at the Turnpike location, exhibits intricate rosette structures.

shanicsburg This town was reportedly named for the repairs needed by the Conestoga wagons before they continued their journey westward across Pennsylvania

In Pennsylvania an important feature related to the Valley and Ridge is the Great Valley The Great Valley lies along the southeastern side of the Valley and Ridge Province and is referred to by the Pennsylvania Geologic Survey as the "Great Valley Section of the Ridge and Valley Province" I am not sure why they call it the "Ridge and Valley" while others call it the "Valley and Ridge" The rocks within the Great Valley are a complex sequence of early Paleozoic limestones, dolomites and shales, and they have been folded, faulted, and often overturned The overall relief in the Great Valley is minimal, as the rocks have been eroded to a nearly flat surface

One of the interesting aspects of carbonate rocks such as limestones and dolomites is that they are prone to leaching by surface water and groundwater. Insoluble minerals, which are sometimes unique, are left behind This can happen in younger as well as older carbonates, but obviously early Paleozoic carbonates that have been folded, faulted, and subjected to millions of years of leaching will be more likely to have dissolved

The Rockdale Run Formation of the Beckmantown Group which is Lower Ordovician in age, is a key unit within the Great Valley rocks It is an excellent example of a carbonate that contained some interesting mineralization The Rockdale Run Formation is principally a dolomite and as such is subjected to significant potential for leaching from groundwater The upper part of the Rockdale Run Formation is reported to contain rosettes of quartz, which have been called "cabbage head quartz"

I was introduced to cabbage head quartz by my friend Ed Charles, who is a key member of the Central Pennsylvania Mineral Club Ed had some pieces for sale during a field trip to a local quarry, and I was immediately impressed with their appearance which reminded me of stromatolites. Stromatolites are among the oldest fossils in the world and are silica replacements of algae The deposition patterns of the silica often form multiple concentric bands, and the pattern can be quite striking

I purchased a few rosettes, along with some publications Ed was selling, and Ed gave me some additional pieces of the rosettes He also provided a copy of an article called "Quartz Roses for Your Rock Garden" with the purchase I thought this was an excellent marketing technique Other mineral sellers may consider providing reprints of articles and technical information about their minerals when they are selling them, as long as they make certain they are not violating any copyrights This can greatly aid in establishing provenance for the sample and assist in future collecting.

However, the article that Ed gave me did not have an author listed, and I did not know what publication it was from The article noted that, while some geologic literature mentioned occurrences of "rosette chert" in central Pennsylvania, there was no information on this type of occurrence in the standard mineralogical references. The writer of the article did an extensive analysis of these rosettes and noted that they were well developed and that the quartz had a banded, concentric structure that was sometimes arranged around a spherical quartz core The rosettes usually completely encircled a specimen, so he believed they were not silica replacements of algae colonies Stromatolite colonies typically have a convex, upward growth pattern Thin sections cut through groups of rosettes also did not show other characteristics of algal colonies.

I observed cut slices of the rosette groups and noted that the inside of such a group contained rounded, clear quartz grains in a matrix of hematite and limonite. The two iron minerals indicated that the quartz grew after or during the oxidation and weathering. The colloform structure of the quartz rosettes also indicated that the quartz likely grew from a colloidal silica gel at low temperature, which would be characteristic of surface weathering conditions. This seems to indicate that the author of the "Quartz Roses" article believed the rosettes formed long after the carbonate was formed, and that the rosette formation may be related to surface conditions.

Unfortunately, the article was less than forthcoming about the location of the rosettes. It gave some references, but they were in name only and the text that Ed had did not list the details of the individual references. Any time you copy an article, always make a copy of the references that are cited, as well, so you can find these if you ever need them It is also smart to copy the front cover or the table of contents of the publication so you have a record of where the article came from I filed the rosette article away until I could find the correct reference.

continued on next page

Cabbage Head Quartz *from page 29*

Fortunately, Ed told me that he had found his specimens at a location just off the Pennsylvania Turnpike Willow Hill exit (Exit 189). This exit leads to state Route 75, and Ed said that I could find the rosettes in the sides of the fields just south of the exit. This location was obviously well outside the area described in the quartz rosette article.

During a trip to Pittsburgh in spring 2005, I took a short break to explore the area south of the Willow Hill exit. The area is on the USGS Fannettsburg Quadrangle and is in Franklin County. The Willow Hill Exit is a very quiet exit and does not get much traffic. I parked at a parking area on the east side of the road where the road from the exit, which is referred to as a connector, ended at a stop sign. The coordinates of my parking area were 40° 05.446' N, 77° 48.571' W, which is in degree, decimal minutes format.

Since it was spring, much of the grass and weeds were starting to grow, and I could not see much on the adjacent farm fields. I looked along the sides of the road and quickly found a nice piece of cabbage head quartz. I soon found several more, though most were quite small. My most striking piece was about the size of an egg. The patterns in the rock were quite extensive, and it resembled a small piece of brain coral.

This was very easy collecting, and it was an excellent break from driving on the Turnpike. I did not see any of the rosettes in bedrock, they were all found loose in the soil adjacent to the road. On the east side of the road there are some outcrops of limestone, and close inspection revealed that fluorite was present. The fluorite was light green and in a small vein in the limestone. I broke it out with my hammer and, to my disappointment, I was not able to find any more. However, I was quite pleased with my pieces of cabbage head quartz, especially the egg-sized piece. I gave a lot of credit to Ed for helping me find this place, and he later gave me permission to reference it for this article. Ed also told me that the copy of the article that he gave me was from *Pennsylvania Geology*, which is published by the Pennsylvania Geologic Survey (717/702-2073, www.dcnr.state.pa.us/topogeo/).

I looked again at the "Quartz Roses" article for clues to other places the rosettes might be found. The author indicated that the rosettes were found in an "abandoned stream channel" in the Mechanicsburg area, near the top of the Rockdale Run Formation. I had no idea what he meant by an abandoned stream channel, as stream channels are not normally abandoned.

A publication by Samuel J. Root dated 1977 and entitled *Geology and Mineral Resources of the Harrisburg West Area, Cumberland and York Counties, Pennsylvania* covered the geology of the Mechanicsburg area, and I thought this would be a good start. This is Atlas 148ab of the Pennsylvania Geologic Survey, and I was able to purchase it at the State Bookstore in Harrisburg. Root mentioned the rosettes in the text, but did not specifically mention the location of the abandoned stream channel. I later read that he had details of a "measured section" in the northwestern section of his geologic map.

Part of the Mechanicsburg site is covered with limestone boulders and heavy brush and briars.

Measuring a section is a basic procedure used by geologists to determine stratigraphic features of a rock unit. It is often used for determining the thickness of individual beds, important structures, and drilling locations. It involves using a tape or other measuring device to literally measure the length of the exposure and note the location of important features, such as bedding, sedimentary structures, fossils, or unusual minerals, such as quartz rosettes.

I routinely measured stratigraphic sections as an undergraduate geology student, and was always amazed at the features that were revealed when a section was measured and plotted on a figure. Unfortunately, this is a skill that I have not seen many geologists use recently. While I know it is still taught in many of the better geology programs, I have found that basic stratigraphy is a skill that many schools are no longer teaching.

However, you cannot measure just any section. In order to measure a section, you must have a significant sequence exposed. The best exposures are often on road cuts, but in the Great Valley of Pennsylvania many of the areas are flat and do not have road cuts or significant exposures. In fact, many of the limestone valleys of central Pennsylvania have practically no significant exposures of bedrock, so every outcrop or hint of rock at the surface is important for geologists mapping an area.

Fortunately, the author of Atlas 148ab had made an excellent geologic map of the area and marked in the text where he measured the section with the quartz rosettes. This was the key to finding the rosette location. The section was marked on a black-and-white map, and I laid this line over the geologic map and noted where the top of the Rockdale Run Formation was mapped. Interestingly, the section was at the edge of the geologic map, not near the center.

Now it remained to be seen whether I could actually access the site. A large Navy base is in the area, and I hoped that the rosette location was not off limits. However, I thought that if Dr. Root could have measured a section in this area, there was a good chance that it was in an area that was accessible by local roads or trails.

I went to the area on a Saturday afternoon in March 2006. I drove down the Carlisle Pike (U.S. Highway 11) to get to the site. The traffic was just awful, and I thought it ironic that I was about to go mineral hunting in one of the most developed areas in Pennsylvania. I was using the geologic map to find the area, and construction along the Carlisle Pike since 1968 had obliterated many of the roads on the map. The Naval Depot, which is also known as the Naval Inventory Control Point, covers a major part of the Mechanicsburg area. I was concerned that the site might be within the closed ground of the Depot.

Knowing how to read a geologic map was important. I had to look for the top of the Rockdale Run Formation. This sounds simple, except when you are dealing with an area with numerous folds and overturned beds. However, there is one geologic law that always holds, and that is the law of superposition. The law of superposition basically states what should be obvious: younger rocks lie on top of older rocks. Of course, later events can obscure this relationship, but it has proved to be a very important concept and is always important to remember in the field.

It is also important to note that this principle is also used in the legends on geologic maps. The legend is always supposed to show the younger rocks at the top of the legend, while the older rocks are below. This is very useful when trying to decipher a complex geologic map. One of my former geology professors, Dr. Lee Woodward from the University of

New Mexico stated that if the legend is not shown in the correct chronological order, it is probably not a good geologic map. This appears to be true as every geologic map I have seen that does not have the legend in the correct order has proved to be a terrible map.

Knowing this, I had to check the geologic map to see which area of the Rockdale Run was the top. The Rockdale Run was mapped on the very edge of the map next to a stream channel, and I was confident that this was the channel that was referred to in the quartz rosette article. The Rockdale Run Formation was in contact with the Pinesburg Station Formation, which was shown as the next youngest unit on the legend. I knew then that I was at the top of the Rockdale Run, and this had to be the place.

I drove south on Salem Church Road and looked for the first sign of a stream crossing. I quickly came to a small bridge and was able to turn left (east) and park at a small clearing. The coordinates of my parking area were 40 23922 N, 77 00364 W, which I recorded this time in degrees, decimal format. The area is on the Mechanicsburg Quadrangle and is in Cumberland County. The stream on the east side was fenced, but the west side was open. However, the west side also had some small No Trespassing signs.

I was somewhat curious about the signs, as I saw at least two people walking their dogs in the distance down the area of this stream channel. It looked very much like community open space. I asked an adjacent property owner for permission to go in the stream to collect rocks. She said it belonged to the Navy and there was no problem if I wanted to go into the channel. As other people were already in the channel, I went ahead to look for the rosettes.

As I headed west down the channel, the first section was a flat area with some rocks scattered in the bottom, but I did not find any rosettes. I soon came across an area of carbonate boulders, and looked between them in the crevices. I found one of the rosettes, and knew then I was at the correct place. I found this rosette at 40 23931 N, 77 00445 W.

The stream channel was totally dry, but some of the grass on the bottom of the channel showed evidence of periodic flow. It fit the description of an "abandoned stream channel." Since I was visiting the area in late March, the vegetation had not grown in, but I noticed a significant amount of briars and thorns around the boulders in the stream. I had long pants, but my legs still got scratched to the point of bleeding. The area of the boulders would not be a good place to come in late summer, as they would likely be covered with briars.

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Cabbage Head Quartz *from page 31*

As I headed farther west, I soon came upon a small playground on the north side of the streambed. This was part of a residential development, and the grass from the playground extended nearly all the way to the stream channel. This was great, as when I return to the site, I believe I could use the excuse that I was taking my kids to the playground. They could play on the swings while I hunted for rocks, and I could keep my eye on them at all times, as the playground was right next to the stream.

Even better, the stream flattened in this area, and a wide swath of gravels was exposed. I immediately began to find excellent rosettes. This area was at 40.23875° N, 77.00593° W. Some of the more interesting pieces, which had a bull's-eye pattern that resembled an orbicle, were quite small, only about ½ inch wide. The biggest pieces were about the size of my fist and had nice rosette structures. I cracked one of them open and noticed a strong sulfur smell, however, I did not see any pyrite or other sulfides in any of the pieces. I had brought a 5-gallon bucket and was able to easily find and carry out several pounds of rosettes, while leaving many behind for future collectors.

Many of the rosettes have iron staining, and there is virtually no carbonate remaining on them. Some of the rocks were covered with a dark green algaelike residue, and I tried soaking them in separate pails of sulfamic acid and a strong bleach solution to see if I could get them any cleaner. I wanted to use some oxalic acid, but I could not find a suitably strong solution at my local hardware store. The acid, bleach, and scrubbing with a wire brush and toothbrush removed some of the dirt and organic material, but it was almost impossible to remove the iron staining. Still, the rosettes look much nicer when the surfaces are cleaned, and I have accepted that the iron staining must remain.

I have kept the best pieces for my display and put the rest in the garden area around my mailbox. A nice aspect of these rosettes is that they are excellent for both display cases and garden rocks. The rocks are extremely durable and are well suited for rock gardens. This is a good change from the other rocks I have used for rock gardens, like my fossils in shale, which disintegrated, or my purple fluorites, which were destroyed by ultraviolet radiation from the sun.

I later went to the Pennsylvania Geologic Survey to see if I could find the original quartz rosette article. I perused all the back issues I could find of *Pennsylvania Geology*. (Looking through old publications is also a good technique for finding other interesting sites.) During my search, I found an article that referenced a huge quartz crystal found by Dr. Samuel Root during his geologic mapping for the Pennsylvania Geologic Survey in Cumberland County. This quartz crystal was found in a stone pile in a farm field about 9,000 feet west-southwest of New Kingston. This article was in Vol. 4/6, and it also referenced the quartz rosettes article as published in Vol. 1/8 of *Pennsylvania Geology*. I had to ask the survey staff to help me find the copy, as apparently the early issues were not on the regular shelves. This time, I copied the entire article and its references.

Interestingly, the quartz rosette article referenced another publication by Dr. Root, which was Pennsylvania Geologic Survey Atlas 119cd, *Geology and Mineral Resources of Southeastern Franklin County, Pennsylvania* published in 1968. Since the Turnpike location was in Franklin County, this might have additional information about that site. I have not yet had the opportunity to review this publication, but hope to in the near future. I suspect this might have helped Ed Charles find the location on the turnpike, but I have not had the chance to discuss this with Ed.

Both the locations offer collecting that is about as easy as it gets. I thought the Turnpike site seemed to have pieces with more crenulations, but the Mechanicsburg site had larger pieces. It could also be interesting to use the geologic map in Atlas 14sab to try to find other areas in which the top of the Rockdale Run Formation is exposed in creek beds or along road cuts. Since this location and its mineralization are not well referenced in the literature, it might be possible to find some locations that have never been collected.

The Turnpike location is great if you are traveling through Pennsylvania and want to take a quick break, and the Mechanicsburg location is excellent if you are in the Harrisburg area and have a couple of hours available. If you are with young kids, the Mechanicsburg location is even better, as they can play on the playground while you collect in the streambed. The collecting sites are also constantly replenished by periodic stream flooding and weathering of the soils, so there should be no problem with finding enough rocks. You are practically guaranteed to find some nice pieces if you go to these sites.

GOLD AND GEM HIGHWAYS

ROADSIDE PANNING SITES IN NEVADA

Part II: Eureka, Humboldt, Lander, Lincoln, Lyon, and Mineral Counties

Story and Maps
by David and Clois Walker

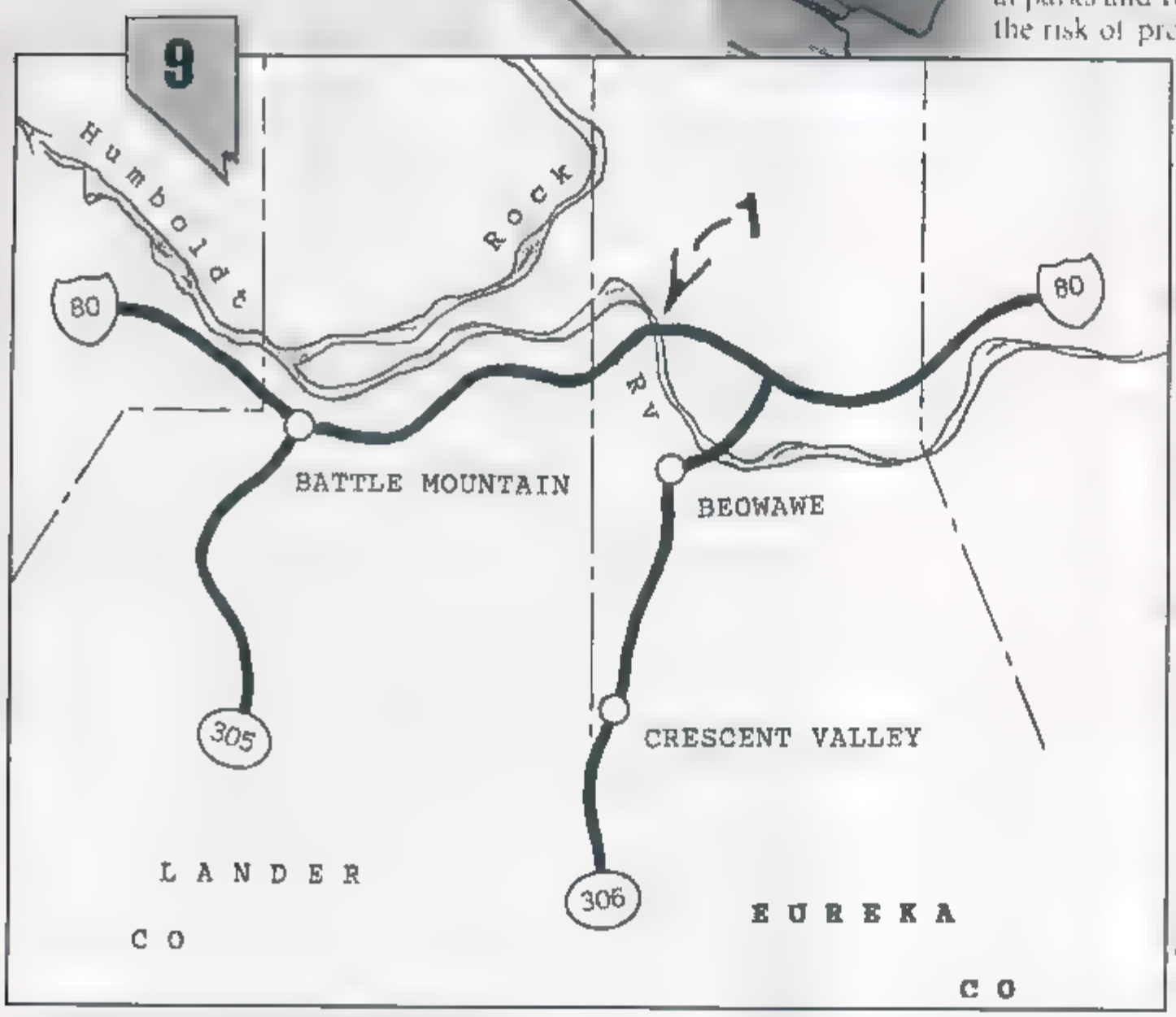
This is the second in a series of three articles containing maps that indicate suggested panning and screening sites at Nevada highway/stream crossings where appreciable finds have been previously reported in vicinity watersheds. The principles of erosion make it likely that minerals and gemstones have been deposited in river gravels, awaiting removal by a rockhound with a pan. Whether conditions at these sites are conducive to panning activities has not been investigated.

By confining operations within government-purchased highway rights of way, panners are spared the necessity of locating and obtaining permission from adjoining property owners, including state and national parks and Indian reservations. However, readers run the risk of prosecution if they cross onto private land, whether purposely or inadvertently. In instances where rights of way have merely been leased, other rules may apply.

Nevada welcomes tourists, but requires permits for panning—a separate permit for each of three state maintenance districts. To obtain encroachment permits and safety guidelines for panning in Nevada rights of way, call (702) 385-6509 (District I office), (775) 834-8330 (District II office), or (775) 777-2715 (District III office), or complete and return the Application and Permit for Occupancy of NDOT Right of Way .pdf form found at www.nevadadot.com/business/forms/. To determine which district to contact, download the NDOT Maintenance Districts map from www.nevadadot.com/traveler/maps/statemaps/. Permits must be obtained *before* you visit these sites.

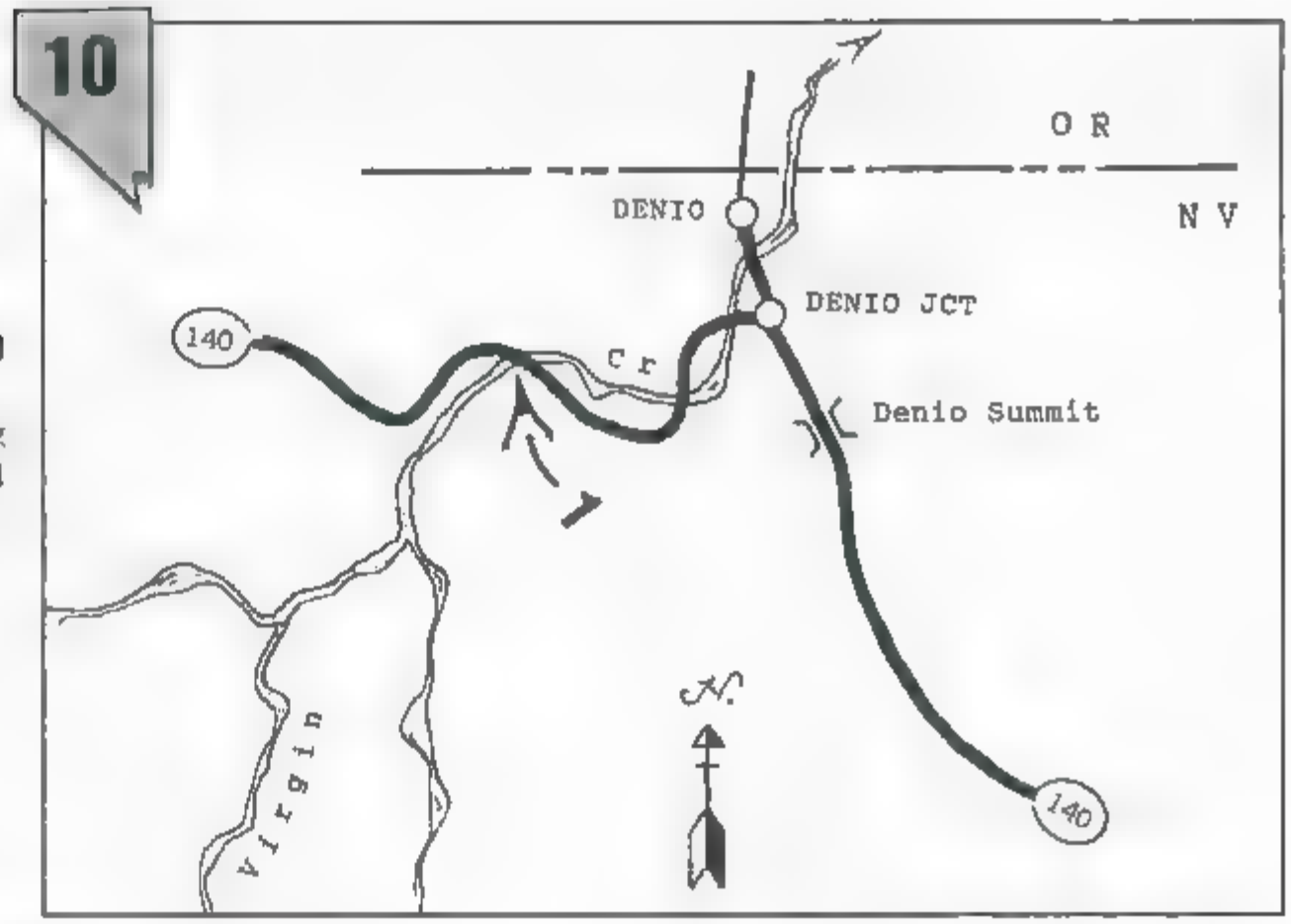
Remember that the government to which these rights of way belong has some regulations of its own. Observe highway safety and environmental standards, such as parking only where designated, and using only a pan and scoop.

The maps provided contain the most up-to-date information available to us, but it's advisable to consult a current state highway or county map when planning an outing, for overall orientation in the field and because highway designations have been known to change.



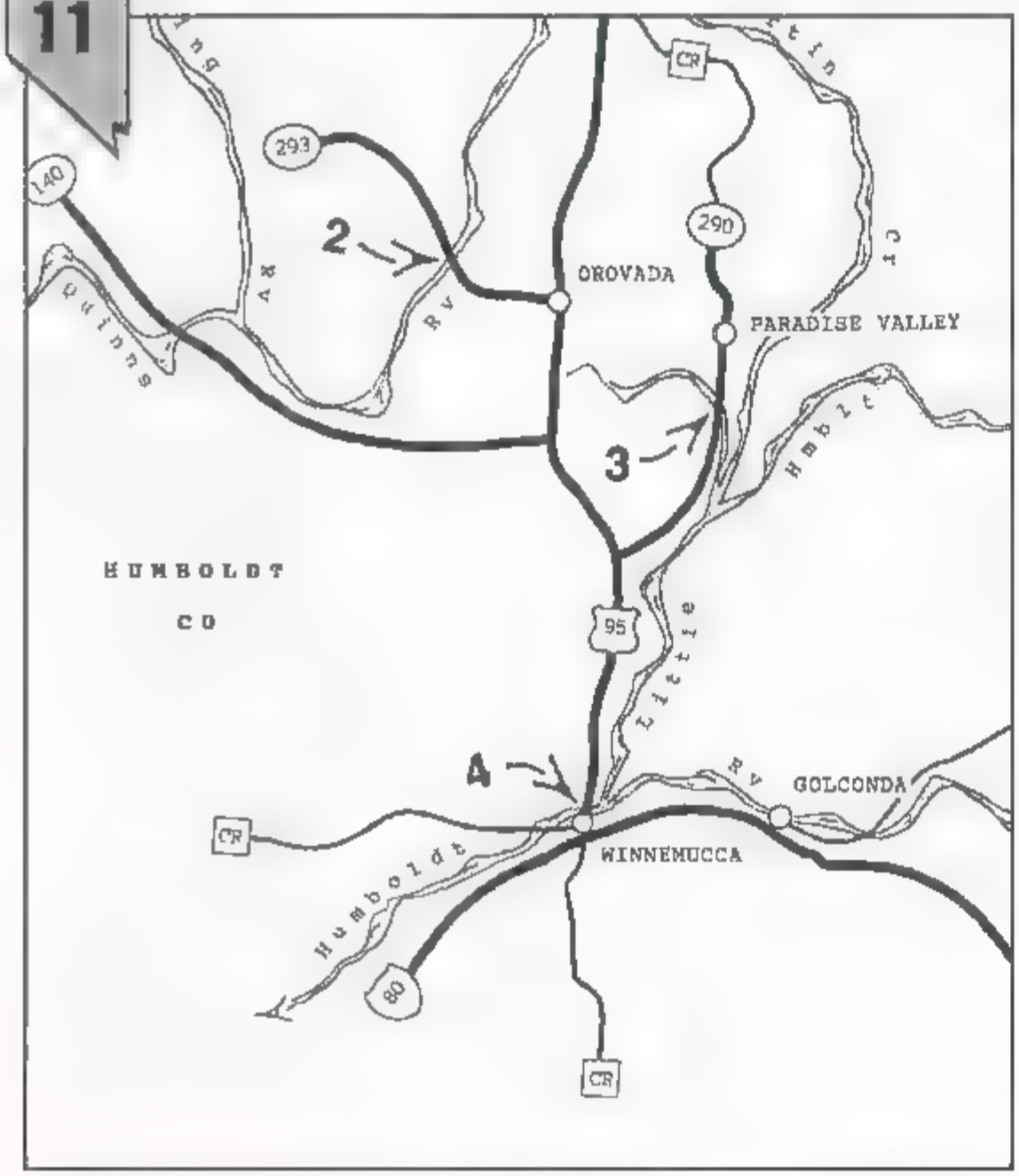
EUREKA COUNTY (MAP NV9)

Site 1 **Humboldt River/Interstate 80** crossing near **Battle Mountain.** Vicinity finds include gold and quartz.



HUMBOLDT COUNTY (MAP NV10)

Site 1. **Virgin Creek/state Route 140** crossing near **Denio Junction.** Vicinity finds indicate gold potential

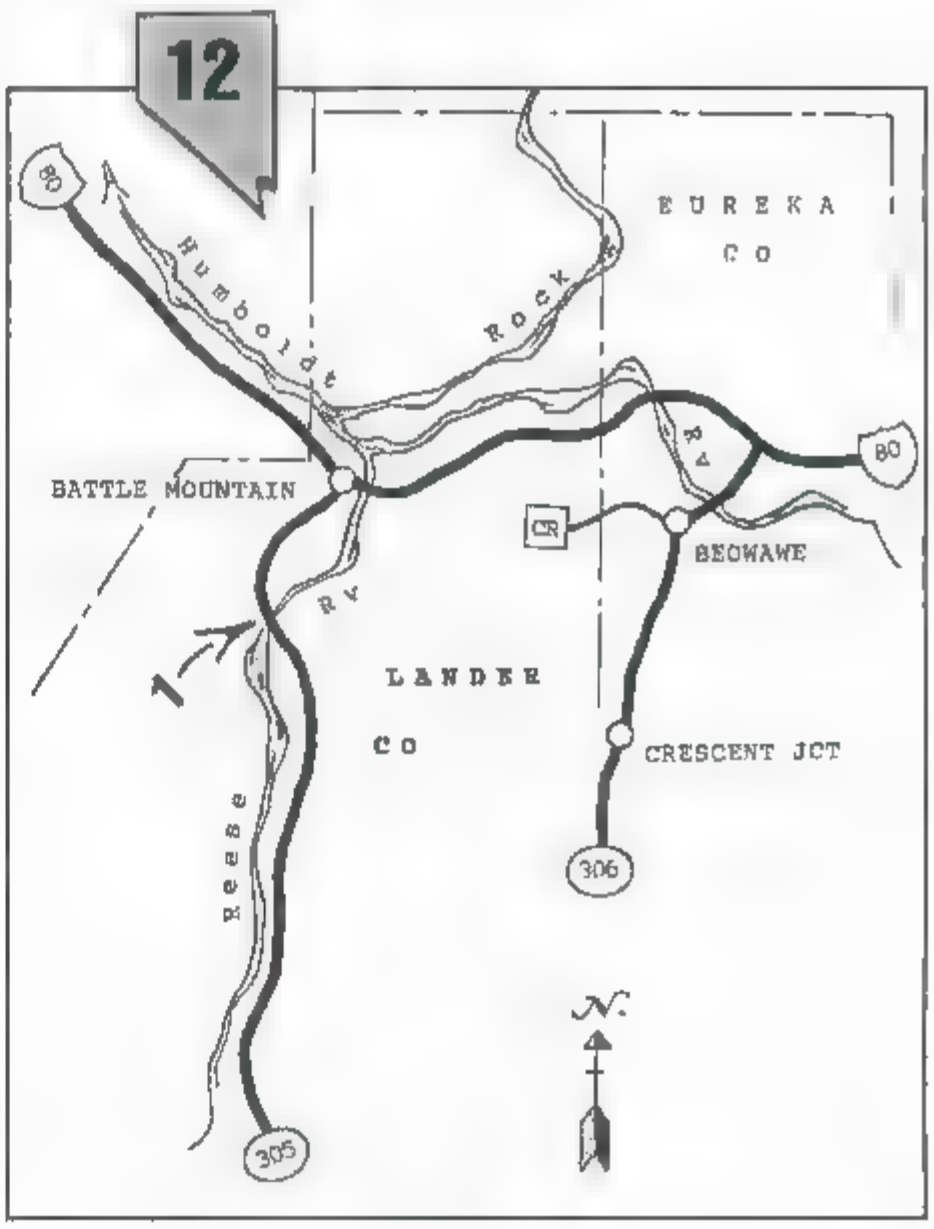


HUMBOLDT COUNTY (MAP NV11)

Site 2 **Quinns River/state Route 293** crossing near **Orovada.** Vicinity finds include gold, platinum and silver

Site 3. **Tributary Little Humboldt River/state Route 290** crossing near **Paradise Valley.** Vicinity finds include gold and platinum.

Site 4 **Humboldt River/U.S. Highway 95** crossing near **Winnemucca.** Vicinity finds include gold, opalized wood, silicified wood, and turquoise.



LANDER COUNTY (MAP NV12)

Site 1 **Reese River/state Route 305** crossing near **Battle Mountain.** Vicinity finds include agate, garnet, gold, jasper, opal, and turquoise.

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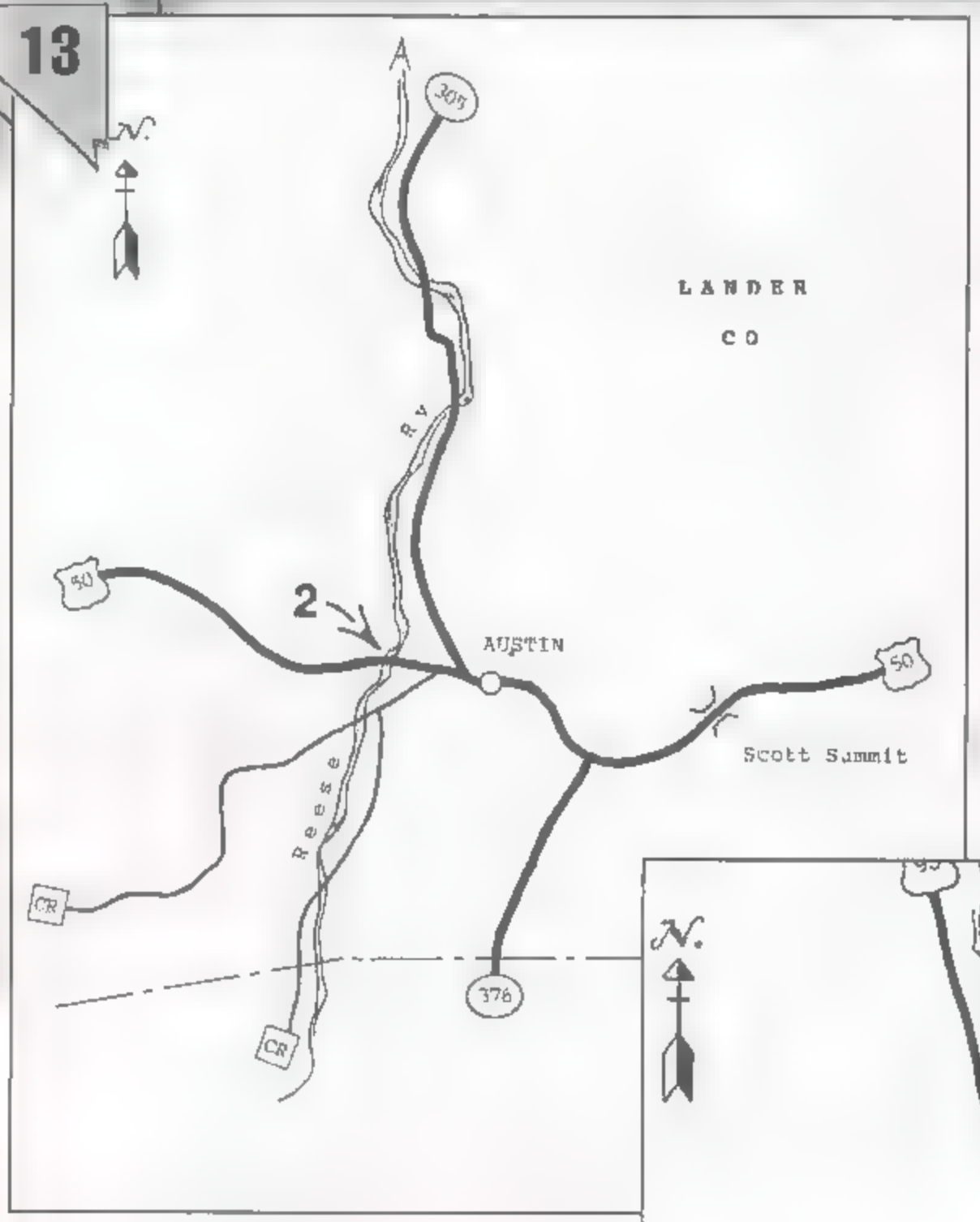
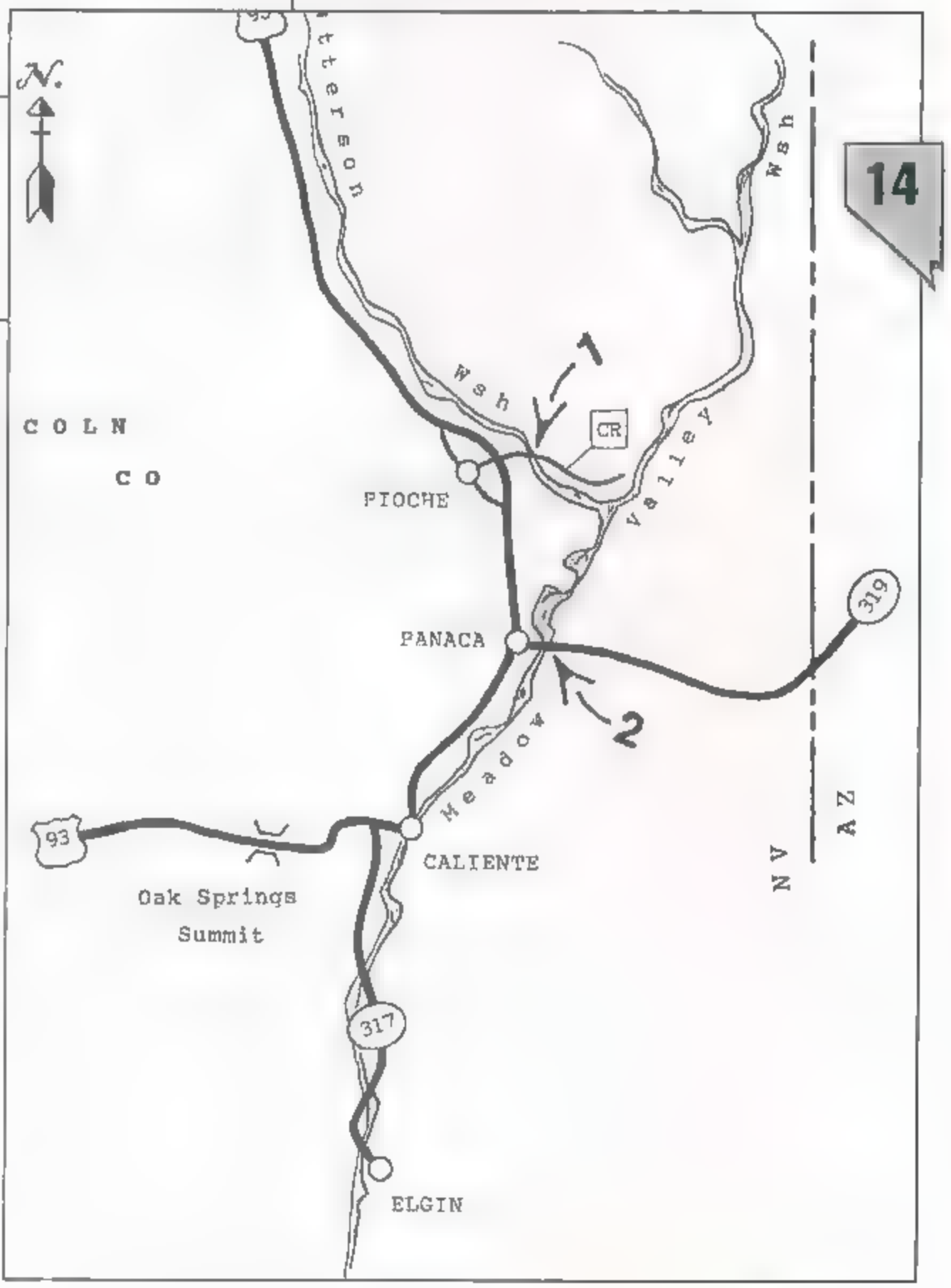


LANDER COUNTY (MAP NV13)

Site 2 **Reese River/U.S. Highway 50** crossing near **Austin.** Vicinity finds include chalcedony, chrysocolla, gold, opal, opalized wood, and turquoise



LINCOLN COUNTY (MAP NV14)

Site 1 **Patterson Wash/County Road** crossing near **Panaca.** Vicinity finds indicate chalcedony potential.

Site 2 **Meadow Valley Wash/state Route 319** crossing near **Panaca.** Vicinity finds include agate, chalcedony, and silicified wood

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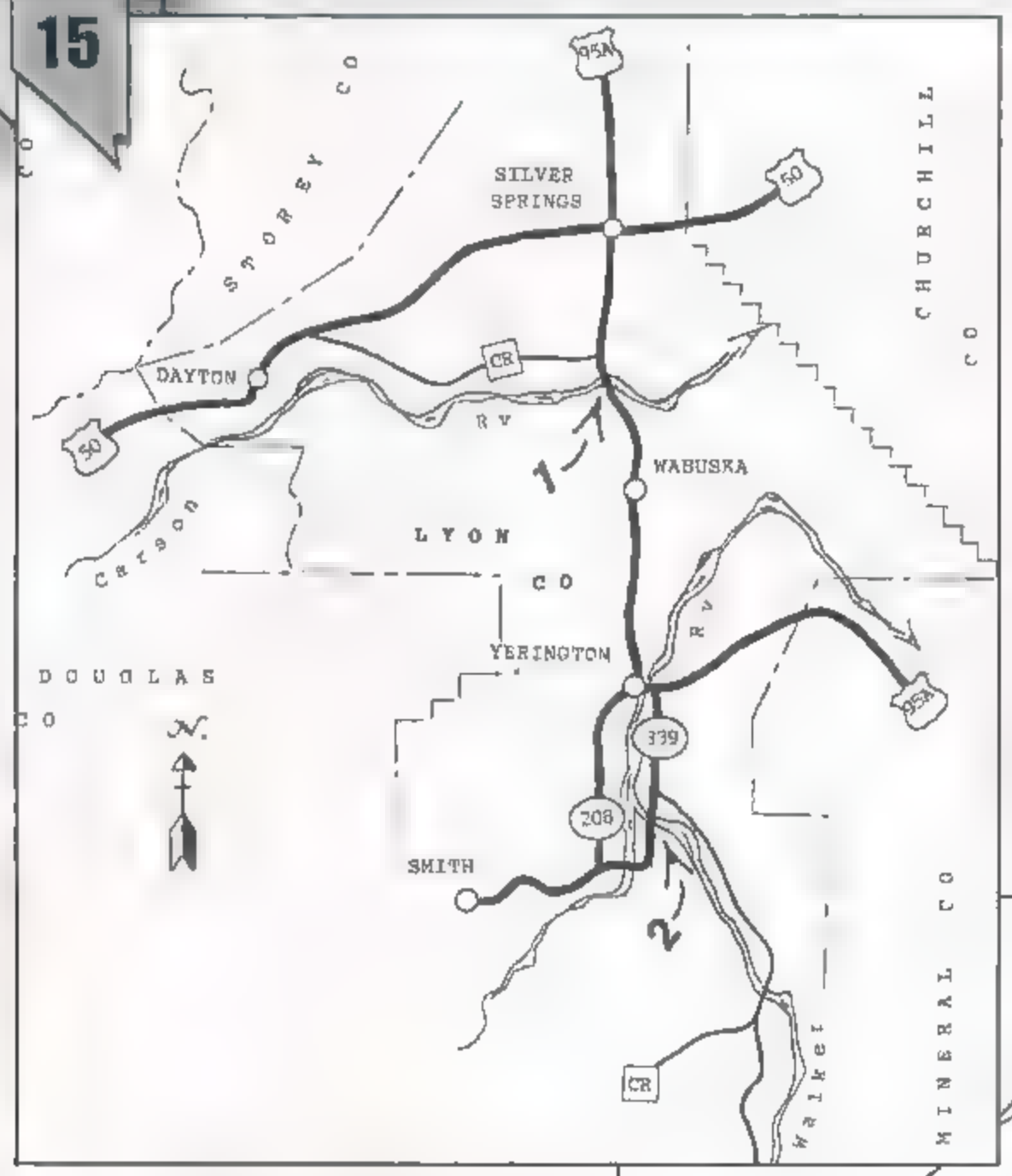
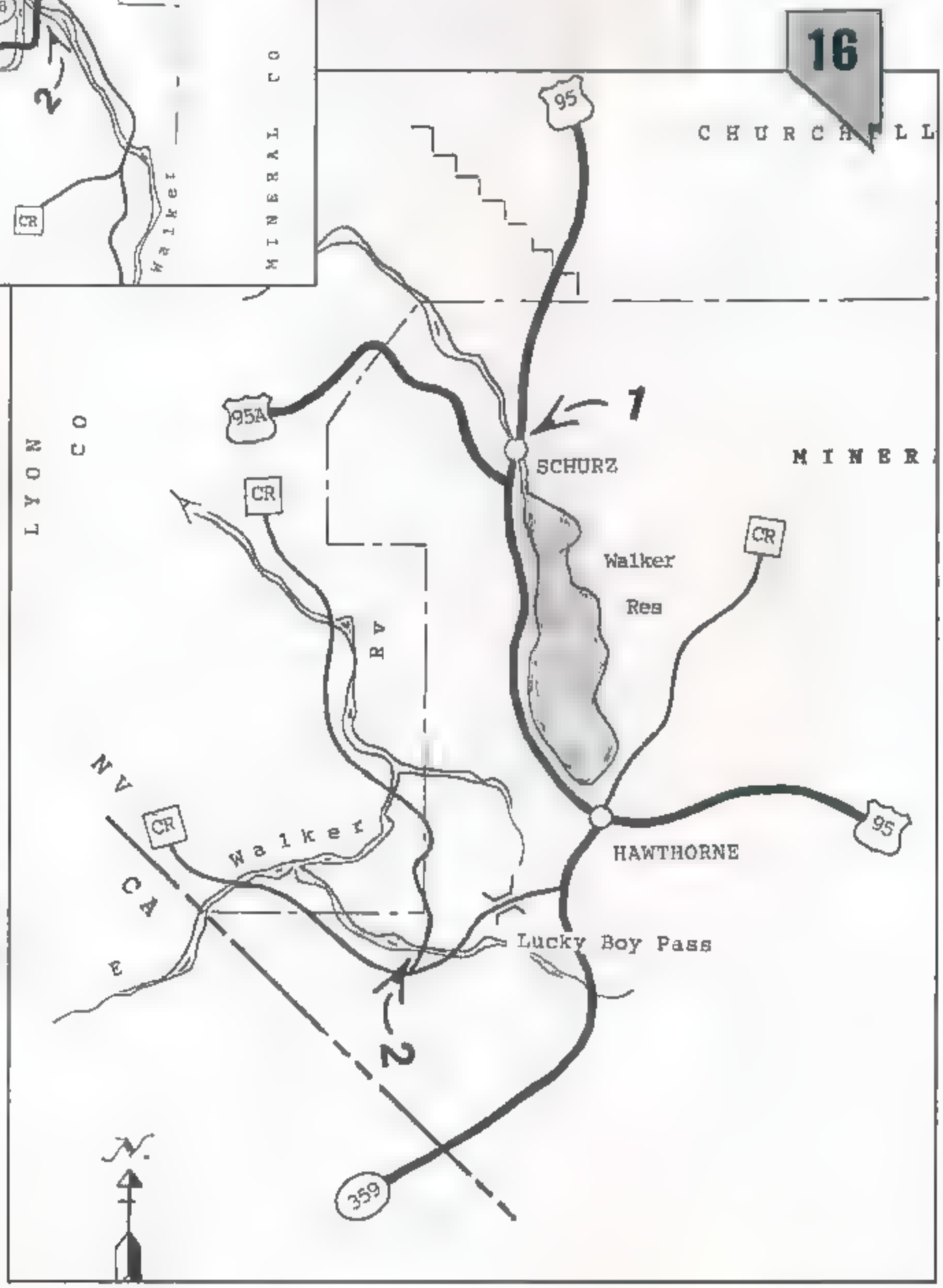


LYON COUNTY (MAP NV15)

Site 1 **Carson River/U.S. Highway 95A** crossing near **Silver Springs.** Vicinity finds include gold and platinum

Site 2 **Walker River/state Route 339** crossing near **Yerington.** Vicinity finds indicate agate, chalcedony, chrysocolla, gold, jasper, silicified wood, and turquoise.



MINERAL COUNTY (MAP NV16)

Site 1 **Outlet Walker Reservoir/U.S. Highway 95** crossing near **Schurz.** Vicinity finds include agate, chalcedony, gold, malachite, silicified wood, silver, and turquoise.

Site 2 **Tributary East Walker River/ County Road** crossing near **Hawthorne.** Vicinity finds include jasper and quartz.

The Minerals of Earth's Crust

Part I: Eight Elements Dominate Earth's Upper Layer

Story and Photos by Bob Jones

Scientists, and more than a few amateurs, have discovered nearly 4,000 different mineral species in the Earth's crust. Yet, by carefully analyzing rocks and minerals, scientists have come to the fascinating conclusion that 99 percent of the Earth's crust is composed of just eight naturally occurring elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium.

These major elements of the Earth's crust have been shown to be the product of atomic fusion in stars like our sun. Our sun, a rather average star, cannot produce any elements heavier than iron (atomic number 26). The formation of heavier elements requires a massive amount of energy, far more than our sun can produce. Such energy can only be generated by an exploding star what we call a nova or supernova!

If eight elements make up 99 percent of the Earth's crust, that leaves a meager 1 percent to account for the remaining 84 elements. Yet, these elements make all the difference in the world when it comes to the great variety of known mineral species. In spite of their limited quantities, we often find these scarce elements concentrated in ore veins and deposits rich enough to be worked productively.

Of the remaining 84 elements, just four make up almost all of that remaining 1 percent of crustal rocks. These four elements are titanium, hydrogen, phosphorus, and manganese. Therefore, 12 elements out of 90 make up well over 99 percent of the Earth's crust. Can that remaining fraction of a percent really account for all the other 80 elements, including such familiar substances as gold, silver, copper, fluorine, uranium, nickel, zinc, lead, and so on? It has to, and it does!

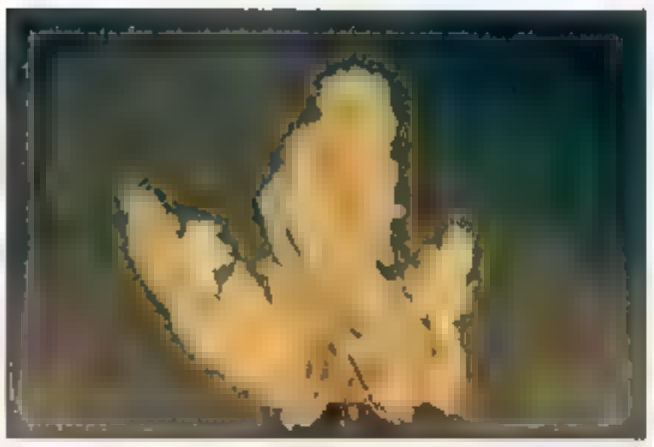
If, as scientists claim, 99 percent of the crust is made up mainly of eight elements, does that mean they occur in equal amounts? Far from it! Scientific analysis has shown that, of those eight, only three—oxygen, silicon and aluminum—make up over 90 percent of the atoms in the Earth's crust. That means iron, calcium, sodium, potassium, and magnesium equal less than 10 percent of the crust's content.

Yet, when you consider that quartz, the most common crustal mineral, is made up of silicon and oxygen, you get a glimpse of just how abundant these two elements are. And remember, aluminum is often an impurity in quartz, and it certainly makes up a high percentage of all the feldspars, which are the next most abundant group of mineral species. They are composed largely of oxygen, silicon and aluminum.

Another curious phenomenon has to do with the size of each element's atom, which is unique. Of the three most common elements, oxygen has the largest atom by volume. Atoms of some elements are really tiny, while others are

Hydrothermal action concentrates teh rare earth that make large crystals of elbaite possible.

Agate is a late-forming silicate that forms in lava rock after the rock has cooled.



COLLECTOR'S EDGE SPECIMEN

Gold was concentrated enough that stunning specimens like this could be mined in Breckenridge, Colorado

G A SPECIMEN

The volatile elements in Earth's crust sometimes are concentrated enough to create colorful liddicoatite tourmaline.

EVAN JONES COLLECTION

The relatively rare element copper is found in concentrated deposits where weathering can develop superb crystals.

really large. The oxygen atom is large compared to the atoms of almost all other elements. It is more than three times as large as an atom of silicon and 10 times larger than a nitrogen atom. Only a couple of elements have atoms larger than oxygen's. Compared to an atom of gold, an element that is exceptionally heavy, oxygen's atom is still a bit larger. Therefore, it is no wonder that oxygen, the most common element, makes up over 90 percent of the Earth's crust by volume.

These figures are cited to give the reader an idea of how extremely rare more than 80 naturally occurring elements really are. Yet, we think nothing of mining huge quantities of metal compounds like lead, gold, zinc, iron and more. Copper, for example, is mined in huge tonnages from dozens of highly concentrated sites we call ore deposits. And we've been mining it for thousands of years! It's hard to believe that a metal as common in society as copper is one of those 80 really scarce elements that comprise less than 1 percent of the Earth's crust!

It is common knowledge that the Earth's crust is composed of three basic rock types: **igneous, sedimentary** and **metamorphic.** It is within these three general rock groups that we have found the nearly 4,000 mineral species, a small number of which we find in decent amounts and sizes to collect. And we're still adding new species on a regular basis!

Each of these three rock groups is subdivided according to how they form. Igneous rock is divided into two subgroups: **intrusive** rock forms within Earth's crust and cools slowly; **extrusive** rock has reached the Earth's surface in a molten state and cools rapidly.

Sedimentary rocks are referred to according to how they formed, i.e. alluvial, eluvial, evaporites, etc.

Metamorphic rocks are divided into two major groups, **regional** and **contact,** and subdivided into several groups according to how the original rocks are changed by heat or pressure or even chemical change.

Regional metamorphism develops due to a combination of two forces, heat and pressure, and covers vast areas. Rocks that are changed by chemical invasion are called **metasomatic** rocks. This chemical action either introduces or removes minerals through hot gases or injected solutions. The familiar porphyry deposits that produce so much copper result from chemical invasion. **Contact metamorphism** is caused by heat flowing into existing rocks from a nearby heat source, which changes the mineralogy. Direct pressure on rocks causes what we call **dynamic metamorphism.** In each case, existing rocks are changed and new minerals created through metamorphism.

Of the three rock types that make up Earth's crust, the majority of the minerals we collect are found in igneous rocks, often as a result of hydrothermal action. Check the section on silicates (SiO_4 minerals) in any mineralogy book. It is certainly the largest section in the book. Granted, metamorphic rock produces lots of silicates, but keep in mind that metamorphic rock has been formed from previously existing rock, including older igneous rock.

Any simple discussion of these three rock types can be a little misleading because there really is no hard and fast boundary separating one rock type from another. A sedimentary rock can shade into metamorphic given enough regional heat. Igneous rock can shade into metamorphic, again given enough heat or pressure.

Take limestone, a sedimentary rock, for instance. It forms on the floor of the ocean or, in a few cases, in deep lakes. It is basically the mineral calcite (calcium carbonate), which is extremely fine-grained, so there is no evidence of crystals. Marble, on the other hand, is calcium carbonate limestone that has been subjected to heat and pressure and completely recrystallized, taking on a sugary appearance.

A problem arises if the amount of heat and pressure is not quite intense enough to cause complete recrystallization. What do we call the rock? Some would call it metamorphosed limestone, which it may well be since it is in between being sedimentary and metamorphic.

We see the same thing when comparing granite and pegmatite rock, a very coarse-grained form of igneous rock. When do you call a rock "granite," though its crystal grains may be fairly large, and when do you call it "pegmatite," though its crystal size may be rather small when compared to pegmatites made up of really huge crystals?

The point is, while we define each rock type in rather specific terms, keep in mind that rock types are interrelated through rocks that are a transition between two definitive types.

continued on next page

Earth's Crust *from page 41*

Igneous rocks form within Earth's crust as a fluid magma. **Magma** is a mix of those top 12 elements. Most important to the formation of so many mineral species are the traces of the 80-odd other elements in that same melt.

Like any liquid, magma can be very fluid or quite viscous depending on its content. The higher the silica content, the more viscous it can be. Of course, viscosity is affected by temperature and/or pressure. Another important factor in the fluidity of magma is what we call **volatile elements.** Fluidity is important to the magma's ability to migrate through existing rock. Water is undoubtedly the biggest contributing factor to the fluidity of any magma. The higher the volatile element content, the more fluid the magma.

Normal magma is composed mainly of silicon, aluminum and oxygen, along with water and calcium, plus a minor amount of other alkali metals like potassium. Mixed in with these common elements are the volatile trace elements, including lithium, boron, rubidium, beryllium, fluorine, and cesium. These contribute to magma's ability to be more fluid. And within that interesting mix are another half-dozen or so less common elements like tantalum, hafnium, thorium, zirconium, molybdenum, thorium, niobium, and uranium. These really scarce metal elements make possible such minerals as zircon, thorite, uraninite, gadolinite, colemanite, topaz, the beryl minerals emerald and aquamarine, and many more species far too numerous to count. Even fluorite (calcium fluoride) is found in pegmatites as a very late-forming mineral, for it represents the very last of those volatiles that remain in solution to the bitter end. They stay in solution until the temperature drops enough for them to crystallize.

Magma gets differentiated depending on where it solidifies. If it remains trapped deep in Earth's crust, it cools exceedingly slowly, perhaps taking millions of years to solidify. If it is as deep as 1,000 miles, it may remain fluid forever. As it cools, over eons of time, large crystals have an great opportunity to develop. If it is closer to the Earth's surface, it cools more quickly, perhaps over thousands of years, and its crystal structure is less coarse. If it reaches the Earth's surface, it bursts forth, and we call it **lava.** It cools very rapidly, and this prevents the formation of visible mineral crystals.

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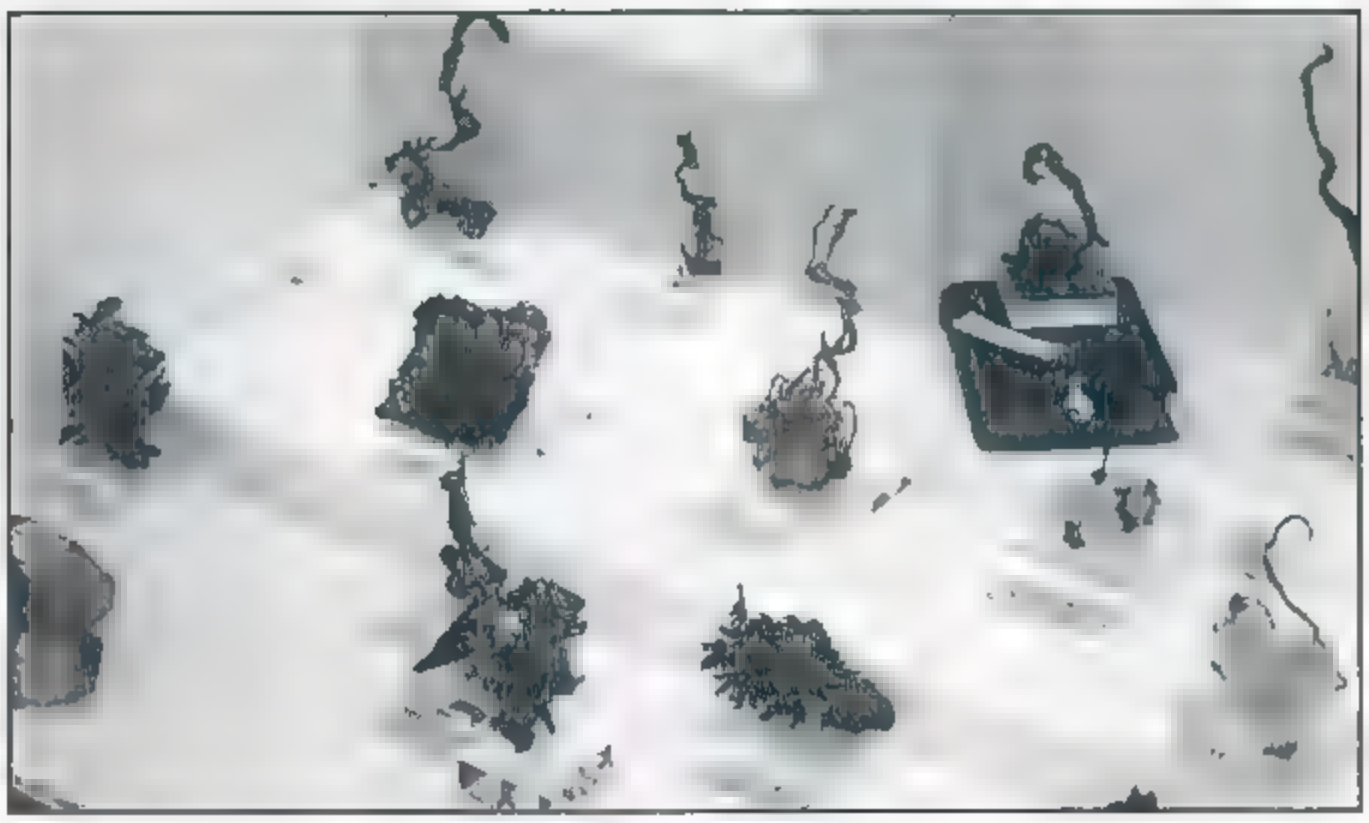


The amount of silver distributed throughout the Earth's crust averages only 1/10 gram per ton of rock

As soon as the red-hot lava reaches the atmosphere, it cools rapidly forming a dark surface as it begins to solidify. The crust that forms over the still-flowing lava, which may travel for hundreds or thousands of feet, acts as an insulator, but the flowing lava still cools very rapidly when compared to magma. Lava that has cooled quickly forms a relatively homogeneous mass. If lava cools extremely rapidly, it takes on a glassy appearance and we call it **obsidian.**

Obsidian is smooth and featureless. It looks black because of the suspended iron-magnesium minerals in it, yet it lacks any evidence of its mineral content. It is, in fact, volcanic glass. You may wonder why obsidian sometimes has gray inclusions. We call this **snowflake obsidian.** The inclusions are the result of water being trapped in the lava. On rare occasion, those gray snowflakes are hollow and contain microscopic crystals that represent the last vestige of the fluids in the lava and the effort of a mineral to crystallize.

At best, lava that has cooled more slowly can have a grainy structure. These grains are minerals that have attempted to form but are prevented from developing completely because the liquid rock has, in effect, frozen before visible, or as scientists say, discrete crystals could form.

Naturally, there are variations on this theme, ranging from volcanic glass to lava that took some time to cool and contains scattered visible crystals, usually of feldspar. They develop quickly and are locked in a dark groundmass of solidified rock.

But, you say, volcanic rock formations are a great place to hunt minerals, including agate and the entire suite of zeolites. And you are right. The reason these minerals are found in volcanic environments is because they are **post-volcanic.** They do not form during the volcanic stage of emplacement, while the lava is molten and cooling. They come along long after the lava has cooled to form basalt, rhyolite, or another extrusive igneous rock.

Agates develop from hot, silica-rich solutions that invade the solid basalt or rhyolite. The watery solution, rich in silica and other dissolved minerals, can penetrate the rock and gather in small openings left by gases. These waters, often from hot spring discharges associated with volcanic action, are hot enough to dissolve a lot of silica and other minerals from the host rock.

The silica solutions fill the gas pockets and continue to cool. When they reach a saturation level, some of the dissolved minerals, especially silica, have to leave the fluid and form a solid, crystalline layer. Once enough silica leaves the solution, stability returns and deposition stops. With each drop in temperature, another layer, or band, of silica forms as agate on the walls of the gas pockets. The cycle repeats until the solution is bereft of silica.

Zeolites also form in gas cavities long after the lava rock has cooled. They often form first on the walls of the cavity, which accounts for some of the sagenitic forms we see in later-formed agate. Most zeolites actually form from watery solutions that may be as cool as 150 degrees F.

Keep in mind there are really three things that control the formation of minerals. Most important is the content of the solution, be it molten rock or hydrothermal solution; a solution rich in a particular metal, like gold, will deposit the metal whenever conditions are right. The other conditions are temperature and pressure, and they play a role in when minerals will form.

If these same noncrystalline, extrusive volcanic rocks are trapped in the Earth and cool, a completely different scenario occurs. This buried, molten rock, **magma,** slowly cools deep in the crust. Since the magma can be over 20 miles deep in the crust, it remains molten for eons of time, slowly losing heat through the overlying crustal blanket. This allows various elements and compounds to slowly migrate toward each other, connect chemically, and develop crystals, the size of which is directly determined by the length of time the mass remains fluid and the availability of material. The kind of crystal that forms is determined by the magma's chemical makeup.

The obvious question about magma is, how does it form? Are the entire deep reaches of the crust completely molten? Or is magma simply a large pool or hot spot of molten rock trapped in more or less solid rock? Using seismic readings from natural and man-made earthquakes, we know the crust is quite solid for the most part. There are pools of molten rock, but they are enclosed in solid crustal rock.

So how does rock in the crust become molten? There seem to be two major sources of heat for this: the immense heat given off by radioactive minerals as they break down in the Earth's crust can create magma pools if it is intense enough. Most magma, however, forms as a result of crustal movement, which creates immense pressure and resulting heat.

The content of the mass also affects how quickly the rock will become fluid and how long it will remain so. Rock containing water is more fluid than rock without water. Also, the greater the amount of volatile elements in a magma, the more fluid it can be.

Determining the major source of pressure on rocks in the Earth's crust brings us to a discussion of plate tectonics, one of the critical processes that create earthquakes, ore veins, volcanoes, and other phenomena.

The Earth's crust is broken into a series of 10 major sections we call **plates.** These 10 huge plates, along with a number of smaller plates, constitute the entire crust of the Earth.

Several of the larger plates form the granite cores of the continents. Granite is less dense than basalt, which makes up the ocean's floors. During the formation of the Earth, the lighter granite tended to float on a sea of denser basalt. The continents were the result.

We know these crustal plates are in constant motion, some moving as much as an inch a year! Others seem not to move at all. The plates are not all going in

the same direction, either. They grind against each other, and some collide with each other. These collisions cause earthquakes and all sorts of interesting geologic phenomena.

You may wonder what makes these massive crustal plates move. All the crustal plates, both granite and basalt, are floating on the exceedingly hot mantle, a region within the Earth that is in constant turmoil and upheaval. We think the mantle is semifluid because of the internal heat being generated within the mantle and core. This heat creates slow currents in the molten rock of the mantle, and this drives the crustal plates. Movement of an inch a year is a lot. As slow as they move, imagine the pressure generated as one plate rubs or collides against another.

When crustal plates crash into each other, one obvious surface result is the building of mountains. Mountains don't just happen overnight, or even over centuries. A 10,000 foot mountain can take millions of years to develop, and as it slowly rises, weathering is trying to wear it down.

For example, the highest peak of the Himalaya Mountains reaches over 29,000 feet above sea level. How did that happen? The subcontinental Indian plate is moving against the Asian continental plate. This is causing crumpling and upthrust along the edge of the Asian plate. The result is the still-rising Himalayas.

As one of the dense basaltic ocean floor plates moves and bumps into a slightly less dense continental plate, something has to give. The edge of the continental plate slowly lifts, but it also crumples, giving rise to mountains. The denser basalt tends to **subduct**, or dip under the continental plate, carrying with it a huge assortment of ocean-floor sediments, minerals, and animal remains that have settled on the ocean floor over eons of time. Subduction and crustal movement is accompanied by earthquakes along major faults, such as the San Andreas fault.

The deeper the ocean basalt plate subducts the continent, the hotter it gets. It eventually melts and becomes a huge, molten mass of **magma.** Now, things that are really hot tend to rise through cooler surroundings. The magma begins to rise toward the Earth's surface, seeking areas of weakness such as faults. It may remain trapped in the crust as a magma pool and slowly cool. If it finds an escape route, however, usually a fault, and gets to the surface, it bursts forth as a **volcano.** At that moment, the magma becomes **lava.**

A great example of this process of subduction and eventual volcanism can be seen in the American Northwest. A map shows a line of active and sometimes dormant volcanoes: Rainier, Baker, Hood, St. Helens, and others. All are the result of a subducted ocean plate along the continental margin!

Crustal plates also crash or rub against each other. In some cases, they draw apart, and this allows hot magma from within the crust to escape as lava. The ocean floor plates of the Atlantic Ocean are separating. At the northern end of this separation, volcanoes have repeatedly erupted, forming Iceland and other landmasses.

Where ocean plates collide, they are well fractured and faulted. This allows ocean water to descend into the crust, heating up as it goes. In addition, there is water that is a natural part of the crustal rocks, called **connate waters.** This water gets superheated, and superheated water is one of the greatest dissolvers of all, even stronger than some acids. As it circulates through the crustal rocks, it is constantly leaching out elements and minerals, gathering them into itself and becoming a rich mineral solution.

This super-hot solution surges upward and invades whatever cracks, faults and fractures it can find. We call this **hydrothermal action,** one of the great natural systems for depositing rich lodes of minerals. We see this hydrothermal action right now along some plate boundaries, where hot, mineral-rich waters gush up into the cold ocean water. We call these oceanic hot springs **black smokers** because they are so rich in dissolved mineral matter the water is actually black.

As soon as this hydrothermal water hits the cold ocean water, it dumps its mineral load and we find layers of sulfides: sphalerite, chalcopyrite, pyrite, galena, and the like — on the ocean floor around a black smoker. It is thought that these may become future ore deposits once that same ocean floor is tilted or folded up to become dry land as a result of plate tectonics!

Gradually, we are identifying what we think are ancient black smoker deposits. The very rich Jerome, Arizona, deposit, from which we mined billions in gold, copper, and other minerals, is one such.

Cyprus is another ancient black smoker deposit. A corner of a crustal plate, rich in minerals from an ancient black smoker, was lifted up by crustal movement to become an island eons ago. The rich iron and copper sulfide ores of Cyprus were mined by the Phoenicians, Greeks and Romans. In fact, our word copper is derived from the Greek word *cuprum* their name for Cyprus.

continued on page 48

The Minerals of Earth's Crust *from page 45*

Hot, mineral-laden solutions may also burst forth as **hot springs** on dry land due to nearby volcanic action. This superheated water cools and starts dropping its minerals, mainly silica in the form of geyserite. These hot springs also bring up other minerals. Since the waters are, by Earth's standards, not exceptionally hot, they are carrying the makings of low-temperature minerals and deposit silica, sulfur, cinnabar, orpiment, and realgar. You're well aware of the stink of sulfur when you are near hot springs like those in Yellowstone Park.

What happens when the mineral-rich waters of the crust don't burst forth as a black smoker or geyser? What happens when they follow a fault system but become trapped by some overlying, impervious rock? While trapped, these hot, mineral laden solutions gradually cool, and this triggers the deposition of their mineral loads. If the mineral load is rich enough in useful metals, a vein system of useful ore will form.

All minerals do not crystallize from solution at the same temperature. Those with a high temperature of crystallization leave the solution first, forming crystals or layers on the wall rock of any available opening, crack, seam, or vug. As the temperature of the solution continues to drop, another mineral in the sequence crystallizes, and so on. Those minerals that remain in solution until the bitter end form atop earlier-formed species. This accounts for the zoning of minerals often seen in ore deposits.

Later crustal movements or mountain building may bring these mineral deposits close to the surface of the Earth, where weathering and erosion expose the mineral deposit to discovery! We find these outcropping deposits through prospecting and, if the deposit is rich enough, we mine them.

This concentration of elements and minerals through the action of hot, subcrustal waters, brought within our reach by crustal movement, is an important process, for it concentrates both common and rare elements and compounds that were originally widely scattered throughout Earth's crustal rocks.

Take silver, for example. It is so abundant in society today that we use it readily in hundreds of ways. It sells for $12 to $15 an ounce. When scientists measured the amount of silver that is distributed throughout the Earth's crust, they found it averaged only gram per ton of rock! If silver had remained so scattered, we certainly could not afford to even consider mining it.

Thank goodness for hydrothermal action, for it has the capability of gathering a rare element like silver and concentrating it in specific ore deposits. Some silver deposits we have mined were so rich in silver—Kongsberg, Norway, and Cobalt, Canada, for example—that masses of the white metal weighing several tons were recovered.

Gold is also brought close to the surface of the Earth by hydrothermal action, and we mine it in quantity. So why is there such a vast difference in the cost of an ounce of gold versus an ounce of silver? For one thing, the average amount of gold in a ton of rock is about gram per ton. In addition, humans prize gold much more highly, so we are willing to pay more for it.

An interesting thing about mining a hydrothermal ore body is the sequential occurrence of minerals. The mines of Cornwall, first worked by the Romans for the tin ore cassiterite, were rich in that rare metal. The Romans actually called the area "the Cassiterides," showing how special the area was for that metal. Yet, scientists have shown that tin averages only 3 grams per ton of crustal rock.

Though tin is a rare metal in the Earth's crust, we find tin oxide cassiterite in high concentration in Cornwall because it has crystallized out of a high-temperature solution that invaded the country rock. So, thanks to hydrothermal action, Cornwall became an important ore deposit region.

As tin mining continued in Cornwall, the tin ore grew leaner and leaner. At the same time, copper sulfides were encountered, showing that cassiterite was deposited first and, as solutions cooled, copper deposition ensued. The Cornish miners were running into bornite, chalcocite, and the like. These minerals crystallize at a lower temperature than cassiterite, so they had remained in solution after the cassiterite content of the solution leaned out.

As the cooling solutions continued to migrate through the fractured rock, they dropped uraninite and then arsenic as each crystallized at its own temperature! So while tin and copper were the important minerals of Cornwall, arsenic minerals were actually in sufficient concentration to constitute an ore mineral.

As solutions cool, minerals can develop into discrete, or visible, crystals, but how does this happen? If you know anything about chemistry, you know that atoms and molecules of the same substance have an affinity for each other. This means they tend to move toward each other through the liquid medium, attaching and building on each other to form larger and larger molecules. In the case of minerals, this sometimes slow, sometimes fast molecular growth can

result in discrete crystals if given enough time and opportunity. This is why concentrations of minerals or elements can occur. Though a magma or hydrothermal solution may contain only small amounts of a particular element, given enough time, that element can concentrate and develop enough crystals to become a significant deposit.

Just how quickly can crystals form? In the science lab, we used to make concentrated solutions and literally watch crystals develop under a microscope. Nature does take a bit longer. One study of pegmatites has shown that crystals can develop in a matter of months. Others obviously take years. The richness of the solution and the effects of temperature and pressure are the keys to crystal growth.

Pegmatite deposits, for example, tend to form deep in the crust where cooling is exceedingly slow. Pegmatites represent rock types that hold some of the largest crystals that have developed. A pegmatite in South Dakota, for example, had spodumene crystals that were 40 feet long. These remarkable deposits can develop crystals that weigh tons and measure yards, not inches.

Most amazing, the overall composition of a pegmatite is virtually the same as granite. Yet, granite never develops crystals of any significant size, as it doesn't cool slowly enough. Instead, partially developed crystals of quartz, mica, feldspar, and less common minerals are interlocked in tight masses of granite. This is one of the reasons granite does not weather very quickly. Granite's tight crystalline structure is also why it is hard and takes a wonderful polish.

While pegmatites may be close to granite in chemical composition, the differences between the two could not be more obvious. While granite is fine grained, pegmatite is extremely coarse grained. Pegmatites are what might be called the final gasp of a deep-seated molten magma mass.

Pegmatites form in two ways. Metamorphic action can develop small pegmatite stringers and veins as it causes some granites to melt into fluid magmas. These, in turn, are injected by pressure into existing cracks and faults where they slowly cool, allowing large crystals of quartz, feldspar, mica, and other minerals to develop. But if this type of pegmatite granite, when it was in the magma state, did not contain a high amount of water and volatile rare elements and minerals, the resulting rock is bereft of rare minerals. We call such rock a **common pegmatite,** for it does not have the necessary ingredients to form exotic mineral species.

Much more important are what we call **lithia pegmatites,** or **complex pegmatites.** What makes these granitic masses so special is that they contain the standard elements found in all granites — silicon, aluminum, oxygen, calcium, and some alkali elements — plus some very special and quite rare ingredients. Complex pegmatites also contain a host of those rare elements that fall within that less-than-1 percent of the crust's composition. In addition to those listed above, they include lithium, boron, beryllium, fluorine, cesium, rubidium, molybdenum, uranium, hafnium, tantalum, niobium, thorium, and zirconium.

These volatile elements, along with an abundance of water, keep the molten mass highly fluid so larger crystals can develop and the melt can penetrate every crack and seam it encounters. These elements remain fluid until the very last, becoming more and more concentrated in the solution so a variety of rare minerals can form in whatever open spaces are left. This is why we search for and find crystal-lined pockets in pegmatites from which we can extract topaz, tourmaline, beryl, spodumene, brazilianite, and a wonderful variety of useful, rare species. Without such mineral sites, we would be hard pressed to mine many useful but rare elements that are normally so widely distributed throughout the Earth's crustal rocks!

This slow crystal growth process explains why we find these rare elements either in crystals, where they are the major constituent, or locked in mineral species as impurities. Fluorite, for example, which is a late-forming mineral in some pegmatites, often has a rare earth element like europium in its composition. Europium gives this otherwise colorless mineral its delicate blue color and even triggers a fluorescent response.

Some of the more exciting and useful minerals we find in complex pegmatites include kunzite, addicoatite, elbaite, tantalite, columbite, and uraninite. The rare elements in these species would never be available to us without this concentrating process.

This discussion gives the reader some insight into how the mineral elements found scattered in the Earth's crust become concentrated enough to be mined for our use. It also helps explain the development of minerals we love to dig for and collect. It all started with the igneous rocks that make up the Earth's crust.

The minerals of the sedimentary and metamorphic rock groups will be described in Parts II and III of this series.

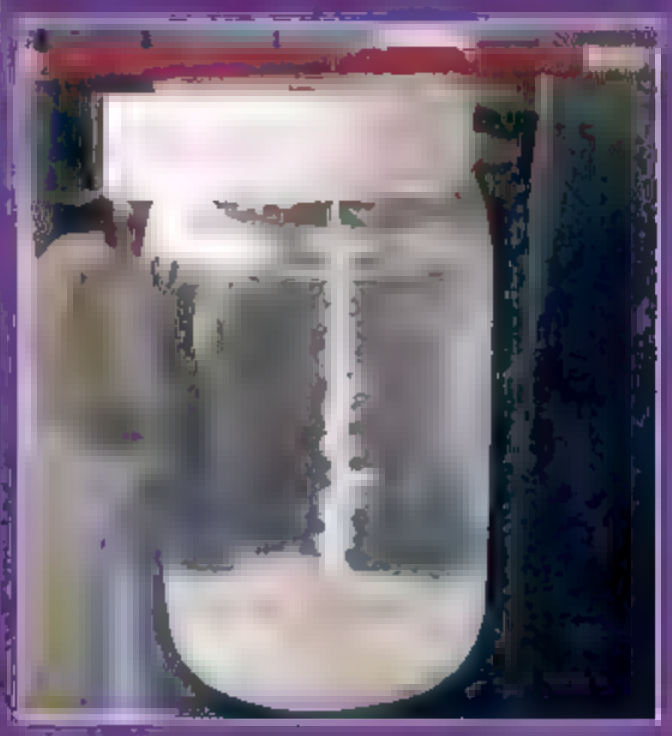
ROCK & GEM

Homemade Halitite Crystals

WHAT YOU WILL NEED:

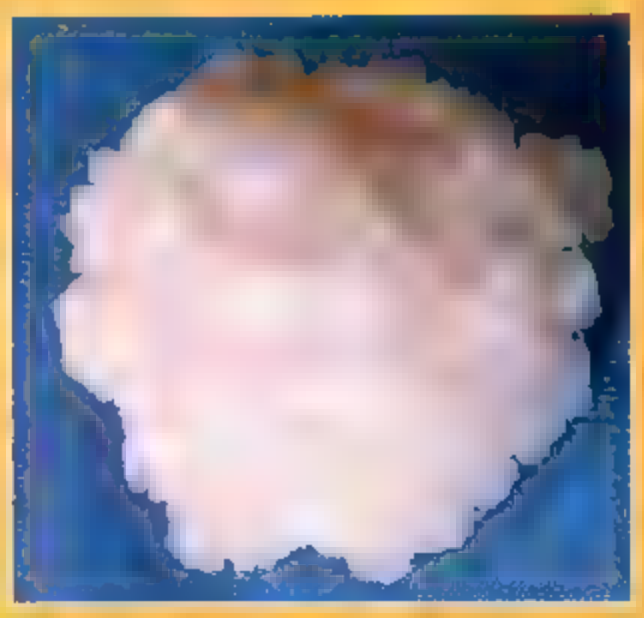
WHAT YOU DO:

With the help of an adult



KIDS

Evaporite Minerals



Halite

We have discussed how selenite roses form in "evaporite deposits." Many other interesting minerals also form in these deposits. They are great for your collection, since they are inexpensive and have cool crystal shapes.

These minerals form from water solutions at normal atmospheric pressure, so they will dissolve in pure water. This means that you can't clean them with fresh water, you must clean them in the same brine they formed in. They may also deliquesce (deteriorate) if they are exposed to the normal moisture in the air for some period of time. You may be able to seal them in plastic containers to protect them. You may have to coat some, like hanksite, with mineral oil to prevent deliquescing.

The Open Pit at Boron, California, is an evaporite deposit in which gray, translucent **kurnakovite** crystals are found. Kurnakovite is a magnesium borate and an ore of borax. A chalky, white outer alteration forms on the crystals when they are exposed to normal humidity, even when stored in plastic containers.

Casts of selenite-after glauberite and calcite-after-glauberite crystals are common at Camp Verde, Arizona. Long ago, **glauberite** (sodium calcium sulfate) crystals were covered by mud that dried out and turned hard as stone. The encased glauberite dissolved, leaving behind a cast, or mold, of the original crystals in the hardened mud. The cast was filled by **selenite** or **calcite** and the resulting crystals retained the distinctive crystal shape of glauberite. When the encasing mud weathers away, these sharp "psuedomorphs" are exposed.

Halite (sodium chloride, or rock salt) is found at many evaporite deposits. At Searles Lake, California, bacteria that live in the salty water often color the halite red, pink or orange. At Camp Verde and in some other localities, blue halite is occasionally found. Background radiation is thought to cause this rare coloration.

Hanksite

Thenardite is sodium sulfate with no water in its chemistry. As thenardite absorbs water from the air, it alters to **mirabilite,** a hydrous (water-bearing) sodium sulfate mineral.

Trona, California, is a great place to collect evaporite minerals. Every October, rockhounds from across the country congregate here to enjoy a great family collecting experience in which everyone is successful. The North American Chemical Co. and the Searles Lake Gem & Mineral Society work together to give hundreds of collectors an unforgettable day of playing in stinky, sticky mud.

Hanksite, halite, borax, trona, and rare sulfohalites such as gaylussite, pirssonite, searlesite, galeite, teepleite, thenardite, nahcolite, northupite, burkeite, and tychite, blown to the surface from deep underground by high-pressure air, can be found in the soupy mud. Everyone scrambles around picking up the crystals, then carries them to the brine to be cleaned. You can't wash these crystals with fresh water or they will dissolve away to nothing!

An opportunity to collect the amazing colored halite crystals at Searles Lake is also offered. It takes a strong, healthy rockhound with heavy digging tools to get into the water and lift out the big halite plates, but once they are on the shore, everyone can find great crystals and wash them off in the brine that is provided. The cubic crystals are often "hoppered," which means they grow in stair step patterns, and the centers may be hollow.

During this event, a two-day gem and mineral show is also going on. It includes a mineral auction and tours of the local chemical plant. What a great way to enjoy the warm Southern California weather!

Rock & Gem Kids Quiz

The Riddle of Rock Art

Pictures Carved — and Painted — in Stone

Story and Photos by Steve Voynick

Southwestern art is an enormously popular contemporary art genre based upon elements and styles borrowed from nature and from traditional Latin American and Native American cultures. Among its major motifs are simple, yet intriguing, designs depicting such recognizable images as human figures, howling coyotes, snakes, bighorn sheep, the sun, and the moon, along with more abstract images that seem to have originated in the artists' imaginations or perhaps even in a supernatural world. Broad variations notwithstanding, all these designs have been borrowed from Native American rock art.

Many rockhounds, especially veteran Southwestern field collectors, are familiar with Native American rock art on a first-hand basis, having prowled remote deserts and unexpectedly encountered ancient, mysterious images adorning boulders, cliffs, and canyon walls.

Rock art is found across much of North America, but is most common and prominent in the greater American Southwest, the states of Arizona, California, Colorado, Nevada, New Mexico, Texas, and Utah. From California's coastal caves to Utah's sandstone canyon walls and south to the sun-baked basalt boulders of the deserts of Arizona and New Mexico, ancient Native American artists have decorated rock surfaces at thousands of sites with their enduring, distinctive images.

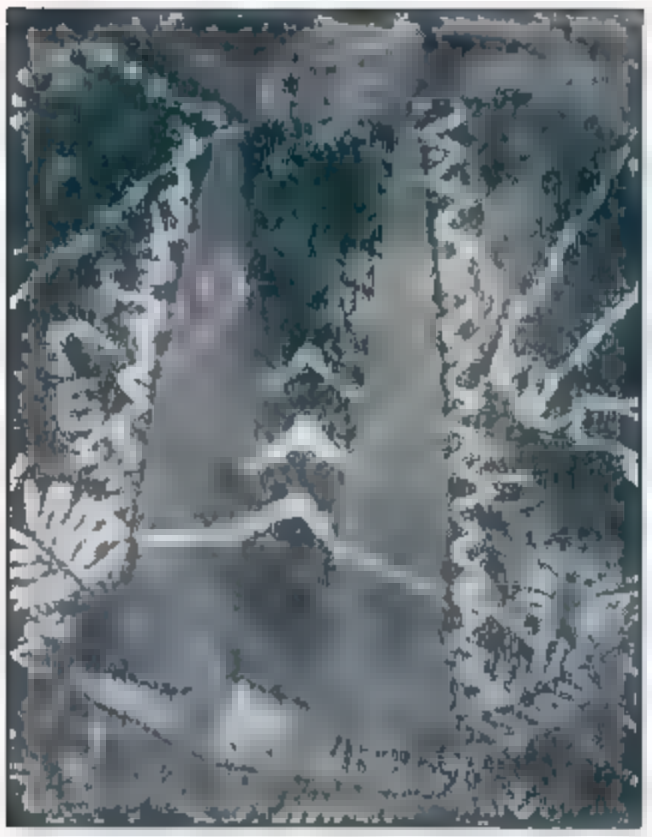
Of all ancient artifacts, rock art, despite its profusion, remains among the least understood. Unlike obviously functional artifacts such as flaked points, baskets, and pottery, the purpose of rock art is much more mysterious. These images on stone have intrigued European settlers for centuries. Cotton Mather, a Massachusetts colonial clergyman and writer, published the first descriptions of Native American rock art in 1690. Since then, many others have attempted to interpret the meaning of the images.

This superb panel of petroglyphs can be seen at Indian Creek State Park in southeastern Utah. Because desert varnish forms so slowly, these petroglyphs will last many thousands of years.

Although modern archeologists and anthropologists have studied rock art for more than a century, they continue to debate who created it, when it was created and, perhaps most importantly, why it was created. They seem to agree only on the matter of how rock art was created.

Rock art falls into two general categories: pictographs, designs painted on rock, and petroglyphs, designs engraved into rock. Ancient Native American artists usually created pictographs on sandstone and limestone, rocks that are typically light-colored, smooth, and fine grained. These artists also selected rock surfaces that were somewhat protected from the elements, such as the walls and ceilings of caves, the walls of canyons, or the semisheltered bases of cliffs. This placement indicates an awareness that the painted images are vulnerable to direct exposure to the elements.

Pictograph paints consisted of a pigment, a binder, and a fluid. The pigment



Anthropologists believe this multichrome Chumash pictograph panel in a cave near Santa Barbara, California was created by shamans in hallucinogenic trances

This fine panel of pictographs at Arizona's Canyon de Chelly National Monument is of Navaho origin and depicts an 1805 Spanish expedition that marched against the Navaho.

was almost always a finely ground mineral, clay or shell. The predominant pictograph color is red because of its high visual impact and the ready availability of hematite, or red iron oxide. Since ancient times, artists worldwide have used hematite, also called ochre, as a red pigment. Hematite is extremely durable, does not fade, and is unaffected by the action of natural acids.

Black, the second most common pictograph color, employed carbon pigments of finely ground charcoal or coal. White pictograph paints utilized pigments derived from dried, powdered white clays or finely ground seashells.

A less common color in pictographs is yellow, which is derived from a pigment of limonite, an abundant, hydrated mixture of iron oxides. When mixed together, red hematite and yellow limonite pigments produce orange pictograph paint.

Blue and green are seen only rarely in pictographs. In the Southwest, these colors are generally restricted to southern Arizona and northern Mexico, areas where Native American artists had access to outcrops of the bright green and blue copper-carbonate minerals malachite and azurite.

Pictograph paints used organic binding agents, such as seed oil, albumin based egg white, extracts pressed from succulent plants, or similar materials that, when mixed with pigments, adhered well to rock surfaces. Water was the fluid that gave paints their proper consistency.

When necessary, pictograph artists first smoothed rock surfaces by abrading away rough or irregular features. Then they applied paints with their fingers or with corn husks, leaves, sticks, or clusters of hair—anything that would give the desired fineness of detail.

While pictograph artists applied paints, petroglyph artists created their images by engraving rock surfaces with four basic techniques. In pecking, they repetitively struck rock surfaces with naturally pointed or flaked stone tools. In drilling, they rapidly rotated flaked stone points mounted on wooden shafts. Scratching involved simple back and forth movements of sharp stone points, grooving was a deeper and more precise scratching technique.

In the North, Midwest and East, Native American artists used hard, quartz based rocks to deeply engrave petroglyphs in relatively soft limestone and sandstone surfaces. In the Southwest, however, petroglyph artists engraved far harder and more durable rock, such as the basalt, granite and gneiss common to the deserts of Nevada, New Mexico, and Arizona. These were shallow engravings that relied not on depth but on color contrast to achieve visual impact. The critical natural element in Southwestern petroglyphs is "desert varnish," the thin, dark patina that forms on the surface of desert rocks over long periods of time.

Scientists once assumed that desert varnish formed when strong direct sunlight combined with microbial action to cause dark-colored iron and manganese oxides to precipitate out of the rock and collect on the surface. They also suspected that desert varnish consisted entirely of iron and manganese oxides, a theory that, although popular, was never proved because the oxide particles were too fine to be analyzed by X-ray diffraction, the main diagnostic tool of mineral identification.

But researchers using infrared spectroscopy, a qualitative analysis technique that illuminates mineral samples with infrared light to determine their infrared absorption and reflection characteristics, have developed new ideas on the origin and composition of desert varnish. Current studies indicate that desert varnish, whether it forms on granite, basalt, rhyolite, quartzite, feldspar, or quartz, really consists of about 70 percent clay and 30 percent manganese and iron oxides.

Nor does desert varnish form from the simple oxidation of mineral components within the rock it covers. The first step in the formation of desert varnish is for fine, wind-blown clay particles and even smaller particles of iron and manganese compounds to gradually collect on rock surfaces as a thin, porous film. Certain bacteria then absorb and oxidize the metal particles, precipitating them as black manganese oxide and reddish-black iron oxide.

Desert varnish thus forms through an interdependent relationship of water, clay, and iron and manganese oxides, combined with bacterial action. Traces of water from dew and rain migrate through tiny pores in the clay and transport the oxide particles, which are then deposited evenly throughout the clay upon evaporation. These oxides and other organic products of bacterial oxidation also combine with the clay particles to form a resistant cementing agent that adheres tenaciously to rock surfaces. Finally, the almost microscopically thin, growing layer of desert varnish shields the bacterial colony from desiccation and intense solar radiation, thus permitting the layer to accumulate to its full thickness.

On average, a fully developed patina of desert varnish is less than 1/10 millimeter thick, yet it is capable of altering the color of entire mountain ranges. It also disguises the surface appearance of individual rocks. A thin coating of desert varnish can make light-colored granites, rhyolites and granodiorites look just like dark basalt.

continued on next page

The Riddle of Rock Art *from page 61*

In the climate and environment of the American Southwest, a "full" patina of desert varnish accumulates in about 10,000 years, a fairly constant period that makes it possible to estimate the age of partial coatings. By estimating the age of desert varnish, geologists can roughly date such landform-altering events as landslides and volcanic eruptions, while archaeologists can roughly date stone artifacts such as flaked points and ax heads that have been exposed on the ground.

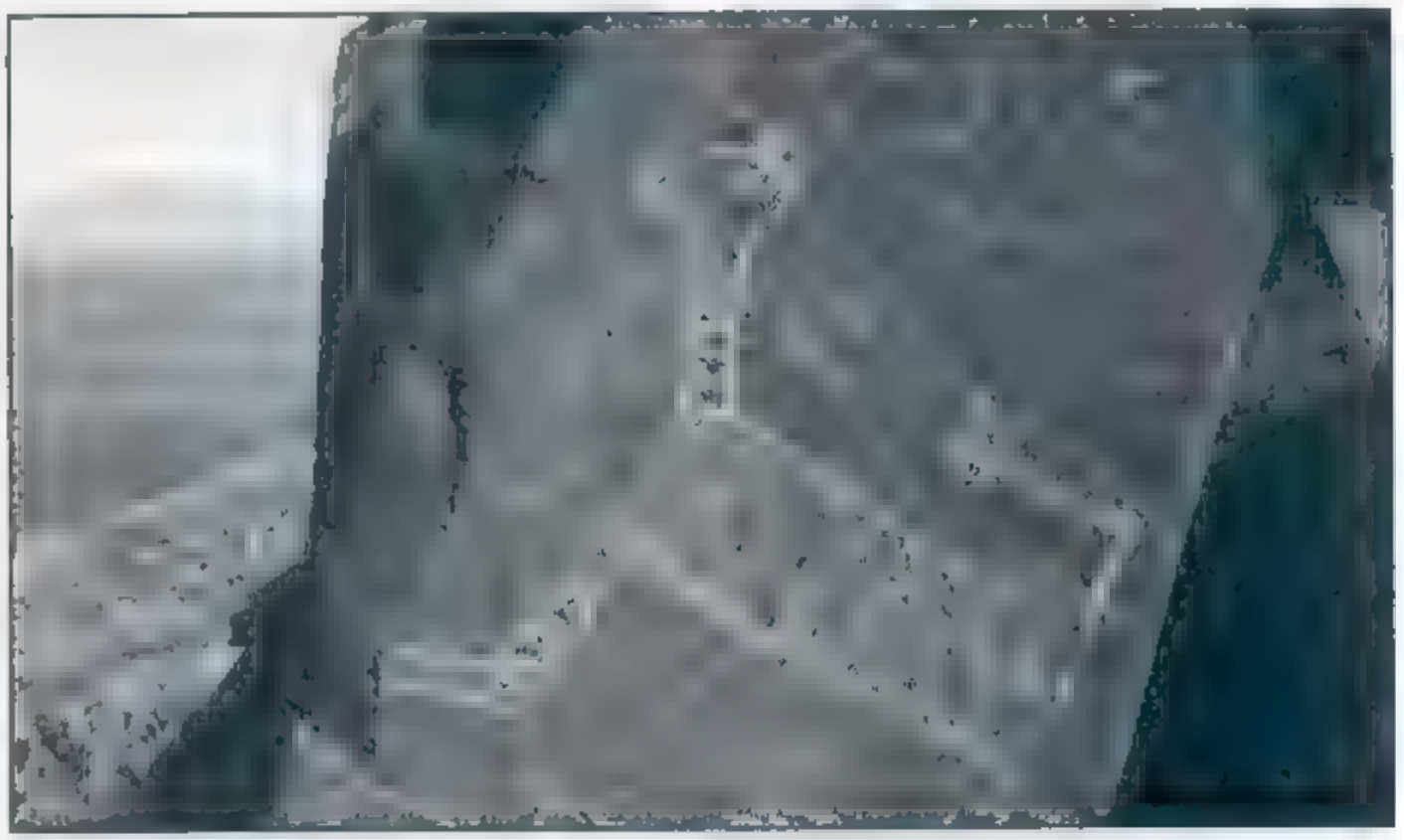
In Southwestern petroglyphs, engraving removes the dark surface patina of desert varnish to expose the lighter-colored underlying rock, thus producing a sharp tonal contrast with the remaining varnish. In time desert varnish will eventually re-form on the engraved area, gradually reducing this tonal contrast. But because desert varnish forms so slowly, petroglyph images last for thousands of years.

Attempts to precisely date rock art, either by absolute (direct) or relative (indirect) methods, have brought only mixed results. In absolute dating, estimations of the age of new desert varnish forming on engraved petroglyph surfaces can vary widely. Even radiometric dating, using the carbon-14 method to establish the age of organic binder materials in pictograph paints and bits of carbon dust trapped beneath paints or newly formed desert varnish, produces unreliable results. The problem lies not in the carbon-14 analysis itself, but in being certain that the tiny organic samples do indeed reflect the time period when the rock art was created.

Relative dating refers to the practice of attempting to link rock art to nearby cultural ruins or artifacts, the age of which may be known. This approach, however, assumes that the rock art and the artifacts or ruins are indeed related. The only unquestioned relative dating method is based on representational art itself, such as images of Spanish explorers in helmets, Christian crosses, and horses, which were obviously made after the arrival of the Spanish.

Because ancient Native Americans left no written records to define their histories, true identities, and styles of rock art, archaeologists cannot always positively identify the cultures that created specific rock-art displays. Only rarely can extant tribes, even those with strong oral history traditions, offer positive information as to the origin of specific rock-art sites.

But the biggest question surrounding rock art remains its meaning. Early anthropologists who studied South-



This New Mexico petroglyph depicts an animal and was made by removing the surface layer of dark desert varnish to reveal the lighter rock beneath.

western rock art considered the images primarily from a representational standpoint. As an example, stylized animal images appearing together with anthropomorphic figures holding weapons logically depicted a hunting-related event. Geometric images such as circles were thought to be solar or lunar symbols tied to seasonal or astronomical cycles. Lines or combinations of lines were assumed to represent trails, terrain features, and territorial boundaries, or were clan symbols or mnemonic devices for remembering important events.

Some early scientists even relegated rock art to ancient forms of graffiti, an idea later rejected on the grounds that the creation of pictographs and petroglyphs that would endure for hundreds and even thousands of years were never casual activities, but thoughtful projects that demanded major commitments of time and effort. Modern scientists also point out that many panels, or groups, of rock-art images are located in nearly inaccessible areas high on cliffs or cave ceilings, places that would hardly appeal to casual artists.

Most anthropologists now believe that the biggest motivation behind the creation of rock art was spiritualism that was often enhanced by hallucinogenic trances. All ancient Native American cultures used rituals, magic and spiritualism to explain nature's dualities, such as life and death, day and night, summer and winter, rain and drought, and health and sickness. Thus considered, rock art can be explained as a graphic expression of the deep belief systems once used in attempts to gain spiritual control over these dualities.

"It is quite clear in the ethnographic record that [rock art] was made by sha-

The largest figure in this panel of monochrome pictographs from Barrier Canyon, Utah, is more than 6 feet tall.

mans," writes archaeologist Dr. David Whitley of the University of California, Los Angeles. "The sites themselves were shamans' vision quest locales, and the motifs depicted the hallucinatory images seen by shamans when in the supernatural realm."

With shamans, priests who used magic to "control" events serving as conduits, ancient Native Americans celebrated good fortune, mourned misfortune, and marked the passage of astronomical bodies and the seasons, while petitioning benevolent spirits to intervene in their lives. Despite wide geographic distances and vastly differing cultures, much Southwestern rock art is remarkably similar, sharing the same abstract images of curvilinear lines, single and parallel zigzags, meandering lines, single and concentric circles, rectangles, and crosshatching, designs that anthropologists believe reflect basic human perceptions rather than particular environments or life experiences.

Jamake Highwater, an author of Native American descent, believes that rock art images show little concern for particularization and appearance. "The imagery is visionary rather than decorative or representational," Highwater says. "It remains spiritual in the purest sense of the term."

Polly Schaafsma, an author and leading authority on desert rock art, supports Highwater's views. "The oldest and most widespread rock-art configuration in the Southwest consists of elemental abstract designs that are similar over broad areas of the West," Schaafsma writes. "I believe this general style is the material manifestation of an interrelated ideographic system formerly shared throughout by archaic hunting-gathering groups."

Veteran Southern California petroglyph guide Don Moore offers another interesting view of rock art. He believes that rock-art images were inherently mystical to their creators. "Remember that [ancient Native Americans] were a people without written language or everyday acquaintance with graphic forms of expression," Moore explains. "To them, images on stone must have been the embodiment of magic itself and must have conveyed an awesome significance to the aboriginal eye."

Rock art is widespread throughout the greater Southwest, but certain sites have exceptional significance. The shamans of the Chumash culture, which lived for thousands of years along the south central coast of California, created elaborate panels of trichromatic pictographs on basalt outcrops and on the walls of sandstone caves. Today, beautifully preserved Chumash pictographs in the hills above Santa Barbara are a featured attraction at Chumash Painted Cave State Historical Park.

The Western Hemisphere's largest known concentration of aboriginal rock art is found in Southern California's Cosos Mountains, where basalt cliffs are adorned with more than 100,000 petroglyphs, many depicting the desert bighorn sheep.

Utah has more than 7,000 cataloged rock-art sites, many of Anasazi origin. Petroglyphs and spectacular pictographs are attractions at most national parks in its vast Canyonlands region.

In New Mexico, both Chaco Canyon National Monument in the northwest and Petroglyph National Monument east of Albuquerque have thousands of individual petroglyphs.

Arizona has more than 2,500 cataloged rock art sites, many of which contain hundreds of individual petroglyphs. In northeastern Arizona, Canyon de Chelly National Monument is famed for its petroglyphs and large pictograph panels that adorn towering sandstone walls.

Another notable rock-art area is west Texas, where countless superb pictographs adorn the limestone walls of canyons near the Rio Grande, Pecos and Devils rivers.

Whether as pictographs or petroglyphs, rock art is obviously durable, but not indestructible. With each passing year, some of it deteriorates due to natural and man-made forces. The natural forces are those of weathering, which slowly, but inevitably, cause the chemical and physical deterioration of rock surfaces and pictograph paints, along with the continuing growth of new desert varnish.

Man-made deterioration, which unfortunately takes a far greater toll on rock art, can be divided into two categories: unintentional and deliberate. The unintentional includes everything from industry-generated acid rain to touching of pictographs, both of which can alter the delicate chemistry of the ancient paints.

Saddest of all is the destruction of rock art by vandals and "collectors" who attempt to chisel out or otherwise remove images. This situation has become so serious that the current policy of federal land management agencies is not to reveal the locations of rock art sites, except for those along patrolled trails. All rock-art occurrences on federal lands are considered artifacts and are protected as such under the Antiquities Act of 1906.

While continuing to influence contemporary Southwestern art, rock art also supports a growing segment of the regional tourism industry. The greater Southwest now has more than 120 commercial guide services that run backcountry tours to rock-art sites.

The perceived meaning of rock art continues to vary significantly in the eyes of modern beholders. Anthropologists believe that while petroglyphs and pictographs definitely have meaning, they are not hieroglyphics in the sense that they spell out that meaning. Unfortunately, we have no Rosetta Stone to help unravel their messages. So while we may continue to discover, study, record, and catalog rock-art images, our interpretations of them, especially of those expressing the spiritual realm, may always remain shrouded in uncertainty.

With that thought in mind, I think rock-art expert Polly Schaafsma offers the best definition of Native American rock art when she describes the mysterious images as "material artifacts from a nonmaterial realm."

However we define and interpret these ancient pictographs and petroglyphs, it is somehow comforting and satisfying to know that their motifs and styles, and even their shrouded meanings, continue to survive as major elements of contemporary Southwestern art.

Remarkable

They're Windows into Earth's Geological Past

Story and Photos by Steve Voynick

Mines, mine dumps, stream and alluvial deposits, outcrops, cliffs, heavily eroded surfaces, and road cuts are among the sites that interest rockhounds and fossil collectors the most. Of all these, road cuts, those man-made slashes, slopes, embankments, and cliffs that we drive by every day, probably receive the least attention.

Perhaps that's because road cuts are so abundant, so obviously artificial, and so often located on roads and highways with traffic and noise, but few compensating scenic attributes. And since road cuts are certainly convenient in terms of access, it can be hard to believe that sites so readily accessible can be good sources of mineral and fossil specimens. When we do pass road cuts, we are usually on our way somewhere else and in a hurry to get there. The only look that many collectors ever get at road cuts is in the rearview mirror.

For anyone interested in mineralogy, paleontology and geology, however, road cuts are well worth a stop. As potential collecting sites for minerals and fossils, road cuts offer two big advantages: convenience and the fact that most of the digging work has already been done. For amateur geologists, road cuts can also be field exhibits that illustrate fascinating principles of geology.

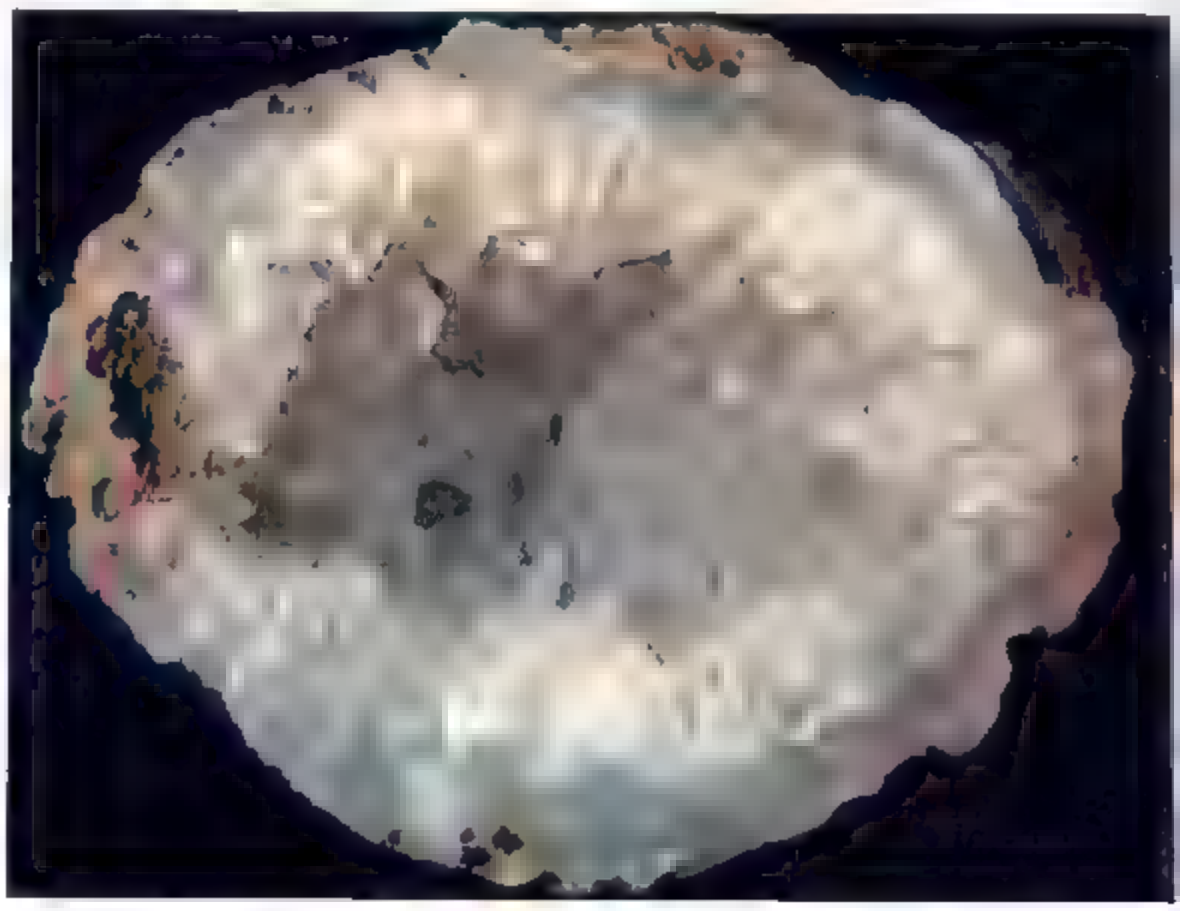
No one recognizes the scientific importance of road cuts better than geologists. In fact, knowledge gained from the study of road, canal and rail road cuts has profoundly impacted the history, development and advancement of their science.

Perhaps no one has pointed out the geological value of road cuts to the public better than the eminent American literary journalist John McPhee, whose name is well known to both professional and amateur earth scientists. In 1978, McPhee, who teaches writing at New Jersey's Princeton University, set out to tell North America's geological story as revealed largely by the road cuts along Interstate 80, the highway that stretches from the Hudson River to San Francisco Bay.

In Italy, McPhee expected this project to take a year. Along the way, however, he became intrigued by the intricacies of geology, geological theory, and the thought processes of geologists. During the next 20 years, McPhee repeatedly criss-crossed the country in the company of numerous geologists, stopping to study road cuts and nearby natural exposures wherever they appeared. In essence, road cuts became his windows into regional geology.

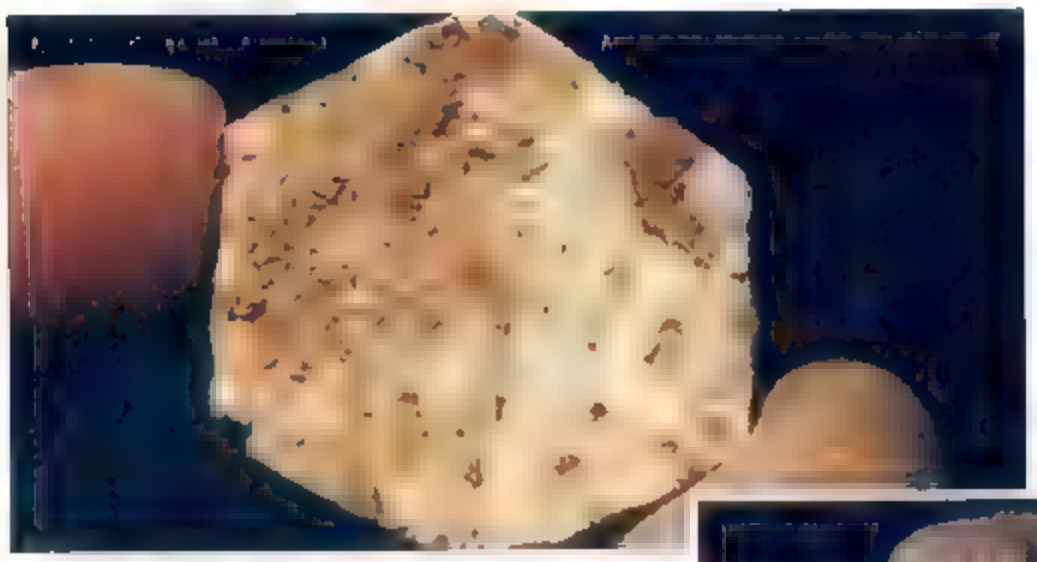
McPhee published the first book about his geological travels, *Basin and Range* (Farrar, Straus and Giroux), in 1980. He followed it with three more books from the same publisher: *In Suspect Terrain* (1983), *Rising From the Plains* (1986), and *Assembling California* (1993). Then, in 1998, McPhee assembled all these texts into *Annals of the Former World*, in which he updated geological facts and theory, and supplemented this combined work with "Crossing the Craton," a new essay about the rocks underlying the central part of the continent.

A large road cut along U.S. Highway 24 just south of Colorado's Battle Mountain Pass exposes the 350 million-year-old limestone of the Leadville formation.

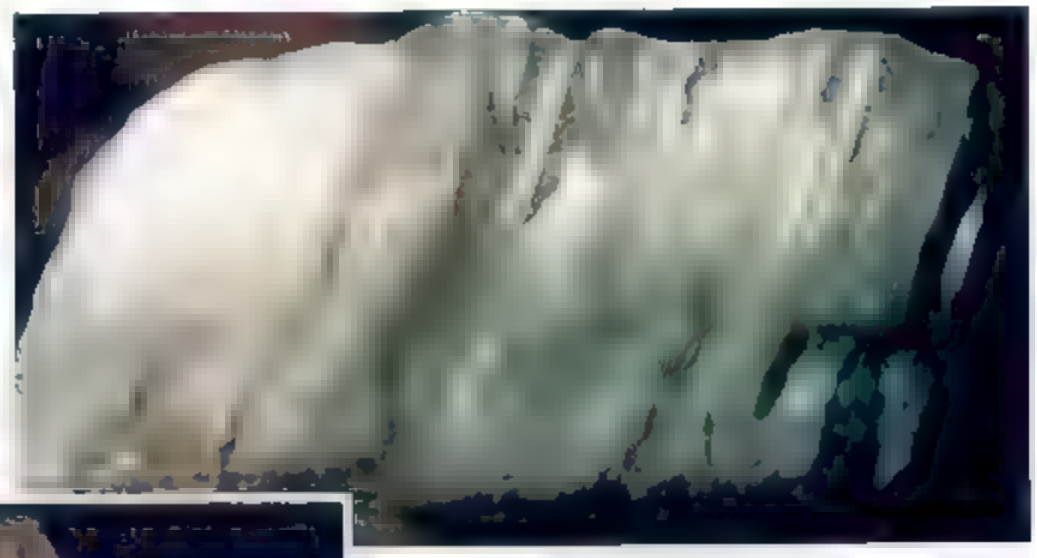


This 2-inch, quartz-filled geode was collected at road cut through volcanic rock near Colorado's Wolf Creek Pass.

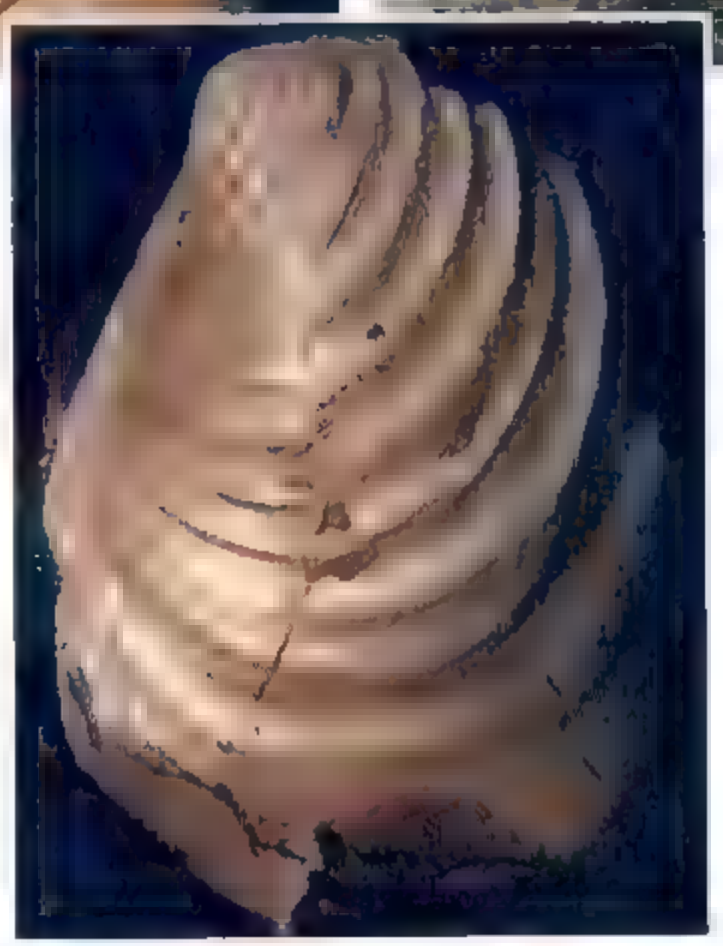
Road Cuts



"Indian dollars," well-formed hexagonal discs of calcite-after-aragonite, are abundant in certain Colorado road cuts.



Numerous road cuts through Colorado's Dakota Hogback Ridge expose sediments laced with seams of satin spar.



Road cuts in the rich Pierre Shale Formation expose its wealth of fossils, such as this mother-of-pearl-covered Inoceramus

Annals of the Former World became a best-seller and won a Pulitzer Prize for nonfiction in 1998, quite an accomplishment for a book on geology. The book, which is at once a North American geology primer, an exploration of plate tectonics, and a study of geological time and the development of the geological timescale, has since enticed countless travelers to pull off roads and highways and see what road cuts have to offer.

McPhee began his geological journey by investigating the I-80 road cuts just west of the Hudson River. His account illustrates the value of certain road cuts to mineral collectors. As an example, in Paterson, New Jersey, I-80 cuts through a vug laden basalt formation that has yielded many fine zeolite mineral specimens. Prior to the building of I-80 in the 1960s, the New Jersey quarries that mined the tough basalt for use in construction and as ballast material provided a good supply of these zeolite specimens, but the quarries were not always accessible to field mineral collectors.

Excavation of the I-80 road cuts at Paterson, which took two years, attracted droves of amateur and professional mineral collectors from across the country who hammered, chiseled and collected superb zeolite crystals as fast as the vugs were exposed. When McPhee visited these road cuts a decade later, he found hundreds of vugs in the exposed basalt walls, every one of which had been cleaned out by mineral collectors.

The geological value of road cuts has been enormous. It is not coincidental that geology's rapid advancement during the early 1800s paralleled the rise of industrial and transportation technology. Previously, the attention of geologists had been restricted to cliffs, caverns, canyon walls, the banks of streams and rivers, and heavily eroded terrain. Although geologists found much exposed rock in desert and polar regions, extreme weathering made it usually unidentifiable. In temperate and tropical climates, geologists encountered only rock that was not only weathered, but usually covered with soil and dense vegetation.

At the time, probing beneath the Earth's surface had been basically limited to mining, but mine workings went down only below mineralized outcrops and other surface indications of ores or valuable rocks such as coal, limestone and marble. Accordingly, early earth scientists understood the rudiments of subsurface geology only from the economic, and not the structural, perspective.

Geology received a major boost in 1815, when British surveyor and engineer William Smith published his *Geological Map of England and Wales*. This was the first geological map in the world to represent the occurrence, distribution and location of various rock strata and types across sections of an entire nation. Smith's ability to compile his revolutionary map stemmed from his work as a canal builder, digging waterways across parts of England. Before they were flooded, these miles of exposed canal walls gave Smith an unprecedented understanding of subsurface geology.

Although the development of core-drilling technology was still more than a half century into the future, the explosive growth of railroad and road systems in the mid-1850s laid open the landscape as never before. This opportunity to observe and study large sections of subsurface rock greatly advanced the understanding of geology, while making geological mapping immeasurably easier. Road cuts also increased public awareness of, and interest in, the rapidly developing science of geology.

Since Smith's time, road cuts have become far larger, thanks to bigger highways, advanced construction techniques and equipment, and the trend toward minimizing road grades and curve radii. Road cuts several hundred feet high and a half-mile long are no longer uncommon.

continued on next page

Remarkable Road Cuts *from page 65*

Although geologists now have the benefit of core drilling and a host of advanced geophysical surveying techniques, road cuts remain important geological tools. During the summer months, geology students and members of professional geological societies are often seen studying road cuts, which are by far the most common destination for all geology field trips.

Despite broadly varying topographies, every state in the nation has an abundance of road cuts. I'm most familiar with those of Colorado, some of which are good collecting sites. A good example is located in northwestern Colorado, where state Route 139 crosses the summit of Douglas Pass and a gravel road leads a few miles east to a Federal Aviation Administration radar station. The collecting site is just below the prominent radar dome, where a shallow road cut exposes strata of crumbly, thinly laminated, 50-million-year-old Green River Formation (Eocene) shale that is rich in leaf, stem and insect fossils. Because the fossilization process here has completely carbonized the original organic matter, the detailed, near black fossil impressions contrast sharply with the light-gray shale and make beautiful display specimens.

Another road-cut fossil site was once located along U.S. Highway 24 at Florissant, 35 miles west of Colorado Springs and near Florissant Fossil Beds National Monument, a famed source of museum-grade fossils of 35 million-year-old (Oligocene) plant and insect fossils. A decade ago, a new road cut that widened the highway shoulder exposed the same fossiliferous shale beds that crop out in the national monument. Word spread rapidly among fossil collectors, and many arrived to "work" the shale. The road-cut site became so popular that business dropped off sharply at a nearby fee-collecting area until after the new road cut had been "mined out."

Although most often associated with mountainous or hilly terrain, road cuts are also numerous in the flatlands. Despite the shallow nature of most road cuts on the plains of Colorado, Nebraska, and South Dakota, those that cut through Pierre Shale are fine sources of fossils. Pierre Shale originated some 80 million years ago as sedimentation on the floor of a warm, shallow, Cretaceous sea that teemed with such marine life as the bivalve mollusks Inoceramus (clams) and Ostrea (oysters). Heavy seafloor sedimentation provided excellent burial and fossilization conditions, the reason that Pierre Shale rich is rich in fossils today.

Unlike more durable limestones and sandstones, Pierre Shale weathers and disintegrates quickly. Accordingly, natural outcrops are few and far between, with most Pierre Shale bedrock buried beneath deep layers of soil. Across the plains, however, shallow road cuts often expose unweathered Pierre Shale with its wealth of Inoceramus and similar fossils, many of which are attractively coated with lustrous mother-of-pearl.

Just south of the summit of Battle Mountain Pass, U.S. Highway 24 treads a narrow ledge that has been blasted out of the limestone of the 350-million-year-old Leadville Formation. The road-cut cliff has small pockets that are filled with well-developed crystals of clear calcite.

This 50 million-year-old leaf fossil was found in a shallow western Colorado road cut

Another interesting road cut is located in southwestern Colorado along U.S. Highway 160, eight miles west of the summit of Wolf Creek Pass. In this large, high road cut, extensive blasting has shaped a steep volcanic hillside into a nearly sheer cliff to make room for a roadbed. Here, the dark basalt contains many agate nodules and beautiful quartz geodes, which are found loose at the base of the road cut and in the basalt of the roadside cliff.

What is perhaps Colorado's most impressive road cut is located on Interstate 70 at the Morrison exit (Exit 258), just 15 miles west of Denver. Four hundred feet high and a half-mile long, it slices through the Dakota Hogback, a steeply tilted ridge that dramatically marks the boundary between the mountain and plains geological provinces.

The removal of 25 million tons of rock to create this road cut exposed 20 million years of clearly delineated, late-Jurassic and early-Cretaceous strata in colors ranging from black, purple, and dull brown to tan, bright yellow, and red. Varying in thickness from 1 foot to 100 feet, these strata are the lithified accumulations of sediments from such different paleoenvironments as coastal plains, sea bottoms, beaches, sandbars, estuaries, freshwater marshes, and tidal mudflats.

Both sides of this road cut have paved walkways along the exposed hogback strata. Interpretive signs identify and explain the origin of each of the various strata of sandstones, siltstones, mudstones, claystones, and shales. A close-up study of the road-cut strata helps to put geologic time—not an easy concept to grasp—into a more understandable perspective. At one point on the walkways, visitors can touch the distinct contact between the red Morrison Formation sandstone and the younger, yellow sandstone of the Dakota Formation. These contact sediments were laid down 135 million years ago and represent the exact transition between the Jurassic and Cretaceous periods of the Mesozoic Era.

The Dakota Hogback ridge system extends for more than 100 miles along the border of the Rocky Mountains and the Great Plains of Colorado. Numerous road cuts expose its strata, which sometimes contain gypsum in such collectible forms as satin spar, selenite, and alabaster. Another Hogback find is "Indian dollars," well-formed hexagonal disks that are pseudomorphs of calcite after aragonite.

Road cuts can also further interest in petrography, or the study of rocks. Although petrography is a fascinating science, it lacks the popular appeal of mineralogy. And that is understandable, for surface rocks that are exposed to the elements are always oxidized, weathered, abraded, or discolored, and breaking rocks to expose their unaltered interiors takes considerable time and effort. But at road cuts, that work has already been done.

Road-cut exposures can illustrate the different types of sedimentary, metamorphic, and igneous rocks better than any textbook or field guide. Colorado's I-70 road cut near Morrison, as an example, exposes more than a dozen different types of sedimentary rocks for study and comparison. Farther west into the Colorado Rockies, other I-70 road cuts expose large surfaces of such metamorphic rocks as gneiss and schist. Studying their contorted flow banding, foliation and deformation makes it easier to visualize the plasticity of the rock when it was subject to the heat and pressure of metamorphic processes.

Road cuts in igneous rock formations can display such coarse-textured intrusive rocks as silica-rich granite, intermediate diorite, and silica-poor gabbro, as well as the finer-grained volcanic or extrusive, analogs of these rocks: silica-rich rhyolite, intermediate andesite, and silica-poor basalt. Many target road cuts even provide examples of pegmatitic veining and structural geologic features such as faults, fractures, and contact planes.

Road cuts have occasionally revealed additional surprises, such as paleontological features and mineral deposits of considerable scientific and economic importance. In 1976 amateur paleontologist Betty Spier investigated a road cut under construction just south of Red Deer River in south-central Alberta, Canada. As she expected, the shale was fossiliferous, but Spier's finds exceeded all expectations, prompting her to report the occurrence to paleontologists at the University of Alberta. The site, now formally known as the Joffre Bridge Road Cut Locality, has become Canada's greatest source of Paleocene plant, insect, fish, and mollusk fossils. Today, following 25 years of extensive scientific study, the University of Alberta museum system displays many of the recovered fossils as the focus of a major paleontological exhibit.

Another fossil of great paleontological significance came from a road cut in north-central Pennsylvania's Clinton County. In 2002, paleontologists identified the vertebrate fossil encased in red Devonian sandstone as the arm bone of an ancient creature with characteristics of both fish and tetrapods (limbed animals). The oldest tetrapod fossil ever recovered, this 365 million year old fossilized humerus continues to help paleontologists better understand how marine life adapted to terrestrial environments.

Road cuts have even paid off for prospectors. In 1947, a prospector investigated a new road cut near Placerville, California. His discovery of a gold-bearing quartz vein led to development of the Hazel Creek Mine, a major gold mine.

For anyone other than a geologist or paleontologist, the exposed rock of road cuts can be puzzling. Fortunately, many reference sources are available to help amateurs understand road-cut features. While field mineral and fossil guides often include descriptions of road-cut sites, their listings are far from complete. The key to finding new road-cut collecting sites is the ability to identify exposed formations and rock types. One way to do that is to learn to use geological maps that identify bedrock. These are available from state geological surveys.

Another aid is the popular *Roadside Geology* book series, which covers 25 states, and the *Geology Underfoot* series, which covers parts of five states. Published by Mountain Press Publishing Co. of Missoula, Montana (800-234-5308, www.mountain-press.com), these book series identify and explain geological and topographical features along federal and state highways. Many road cuts are discussed, with their exposed rocks described by formation, origin, type and age, and sometimes even by collectible minerals and fossils.

The legality of road-cut mineral and fossil collecting varies widely. In most cases, collecting minerals or rocks from road cuts for recreational, noncommercial purposes is not restricted. Few if any, counties restrict road-cut mineral collecting, but state regulations are sometimes more stringent, and states own (or lease) the rights of way along both state and interstate highways. It is the responsibility of the individual collector to contact the appropriate state agency and learn the local rules, as well as obtain any necessary permissions or permits before collecting at these sites.

Road-cut fossil collecting is often more tightly restricted. In Colorado, for instance, fossils have been "ordered" into state archaeological-protection regulations. It is therefore illegal to collect any fossils, including those of common plants and invertebrates, along all Colorado state-owned highway rights of way.

When investigating road cuts, it is also wise to keep safety in mind. Be sure to park vehicles well off the shoulder so as not to obstruct traffic. Some sections of state and interstate highways, often those in which road cuts are narrow and close to the shoulders, have posted "No Stopping" rules. Remember, too, that road cuts can be unstable by their nature. Exposed road-cut surfaces are not deeply weathered and are just beginning the long weathering process. Thermal expansion and contraction, along with the freezing and thawing of water in cracks, can cause newly exposed rock, especially on steep faces, to loosen, or "slough" off. Attempting to climb steep road cuts can be dangerous because the rock is not as stable as that of natural cliffs.

In *Annals of the Former World*, John McPhee describes road cuts as "gifts" to geologists. They are also gifts to amateur geologists and to mineral and fossil collectors. Your tax dollars created road cuts, so take advantage of them, enjoy them, and learn from them! After all, unlike many other collecting sites, most of the digging has already been done for you.

FIELD TRIP

ROCKHOUND'S HONEYMOON

Part IV
Hunting Texas Topaz

Honey Creek is a mainly dry creek dotted with granite boulders.

Story and Photos by Kenneth H. Rohn

After my adventures collecting agates in the Cotulla area, I looked forward to a new adventure in the topaz fields of Mason County, Texas.

A year ago, I spent Christmas in Texas. While there, I was not allowed to collect or mine topaz crystals because it was deer hunting season. Right then and there, I made a vow that I'd be back. Therefore, my objective was Mason County to have a try at finding some of those precious topaz crystals.

When I arrived in the city of Mason, Texas, my first stop was the Chamber of Commerce. Thank goodness the office was open. The lady I spoke to was most helpful, and I received sufficient information to be able to proceed from there. As properties and particularly fee mining ventures change from time to time, it's wise to get up-to date information whenever possible. One sheet of paper I received gave directions and information for two topaz mining areas. At random, I chose Cramer Seacrest Honey Creek Topaz Field. Their flier instructed me to "pick up keys at the NU Way Grocery on the northwest corner of the square in Mason."

I will make a wire-wrap cage for my prize water-clear topaz crystal and hang it from a chain.

Once at the city square, I had no trouble in locating the store. I told the lady behind the counter what I wanted to do. She smiled and handed me a waivet form and asked me to sign my name. After paying the nominal fee for all hookups, I departed with the key to the gate and instructions on how to get there.

Some six miles later, I arrived at the gate and followed the main ranch road to the headquarters. I found I had the place all to myself. I was allowed 24 hours to mine for topaz before I had to return the key.

It was quiet here. Once in awhile, I could hear faint highway noises in the distance or the faint bawl of cattle at some water hole, but the setting was serene.

After finding a place to park that suited me—and there's unlimited space here—I walked down to the creek to investigate. I thought as I walked along studying the eroded embankments of this meandering stream, "This is what I'm looking for!" I could almost visualize topaz crystals waiting for me at every step. This partially dry riverbed looked very promising.

I discovered four topaz crystals and one odd concretion at Honey Creek

I began my screening efforts next to one of the boulders, thinking it might have trapped topaz crystals.

When I had set up camp, turned on the gas, and plugged in the power at the pole, I gathered up my equipment, along with a bottle of water and camera, and walked the short distance to Honey Creek. The spot in which I chose to dig was practically dry. I saw a small pool of water downstream a way, but for the most part I was walking on a dry creek bed. I soon learned that this appearance was deceptive.

Topaz, or aluminum fluorosilicate ($Al_2SiO_4(F,OH)_2$), is Texas' state gemstone and the birthstone for November. In Mason County, it occurs in granite outcrops in areas adjacent to the towns of Grit, Katemcy and Streeter. As a rule, it's discovered in streambeds in these areas, and has been mined by private individuals for decades since it was first discovered here. Even today, after much mining activity, diligent collectors can still find gem-quality crystals. I was hoping that I would be so lucky this time around.

Topaz crystals are often found with a very high luster, in fact, glistening with perfection. At other times, they appear to have encountered some chemical reaction after formation, causing them to appear cloudy and lackluster. It's not uncommon to find a perfectly formed topaz crystal with numerous flaws and inclusions in it, making it good for little more than a cabinet specimen. I have several blue crystals in my collection. Some of these certainly must have encountered a chemical reaction at one time long ago. When cut and faceted, clear stones show the true beauty of this mineral, and the great thing about topaz is the fact that it can be purchased at a reasonable price.

At a glance, aluminum fluorosilicate bears a striking resemblance to quartz. This is where the resemblance ends, however. Topaz crystals are found in a variety of colors. The predominant colors in the Mason area are clear, gray and blue. Brown is not that uncommon, but yellow is rare in the United States.

For some unknown reason, the vast majority of people think of topazes as yellow gemstones exclusively. By the same token, not all yellow stones are topazes, although they are often mistaken as such. If you are about to purchase a topaz, make certain that it's the genuine article and not citrine or some other yellow stone that resembles topaz.

As a comparison, quartz has a specific gravity of 2.6 and a Mohs hardness of 7. Its cleavage, as a rule, is practically nonexistent and it rarely exhibits rhombohedral separations. Topaz, on the other hand, has a specific gravity of 3.4 to 3.6 and a Mohs hardness of 8. The cleavage is excellent, often a perfect 90-degree angle in one basal direction, and sometimes so perfect it looks as though it had been deliberately cut by a lapidary.

Topaz crystals are usually found as stubby, prismatic rhombohedral crystals, with occasional striations running lengthwise. They can also be found as granules, but rarely, if ever in massive form.

Topaz occurs in Mason County in what is known as the Llano Uplift. This is a plateau consisting of rather flat hills, without any abrupt mountains. The elevation in which the topaz deposits are found is from 1,600 to 1,800 feet above sea level. Due to this rather flat tableland, the deposits tend to remain more or less stationary. Not many streams flow regularly here, due to the very dry conditions for much of the year, so movement by water flow is minimal. These deposits most certainly must have been broken free from a disintegrated body of massive granite and transported an unknown distance before coming to rest here.

One factor that works against us rockhounds and makes recovery difficult is the fact that topaz is heavier than the gravel surrounding it. It's rarely found lying right on the surface, its natural tendency is to sink down to or near bedrock over time. The topaz-bearing gravel at Garner Seaquist consists of decomposed red granite, along with feldspar and a host of other lighter minerals, including mica.

It was approaching forenoon when I picked a likely looking place next to a large granite boulder and began to shovel gravel into my screen. My logic was that the boulder might have stopped a number of crystals in their tracks. I hoped I was right.

I had built my screen slightly oversized with a ¼-inch mesh and 6-inch sides. I had cut hand holes in each end large enough so that I could use it while wearing gloves. I'll admit it's a bit heavy if overloaded with dirt, but it works like a charm and I can screen a lot of material in an hour.

The anticipation that the next screen will hold a valuable gemstone is what keeps us going, even when tired. This has actually happened on occasion for me. At prolific gem-mining sites in the past, I have been able to recover one, two or three garnets or quartz rock crystals in almost every screen load. But, sadly, that's the exception rather than the rule.

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After just about an hour of digging and screening, I still hadn't found anything of value. During this time, I had studied several screen loads of multi-colored rocks of various sizes, but no topazes came to light. By this time, the hole next to the boulder had filled up with water just below the creek bed.

In this part of Texas, as a rule, it's dry for much of the winter, yet, Honey Creek still held a substantial amount of water just below the surface. The plus to this was that the gravel was being washed before I put it in the screen. A lot of it flowed over the sides of my shovel, before it reached the screen.

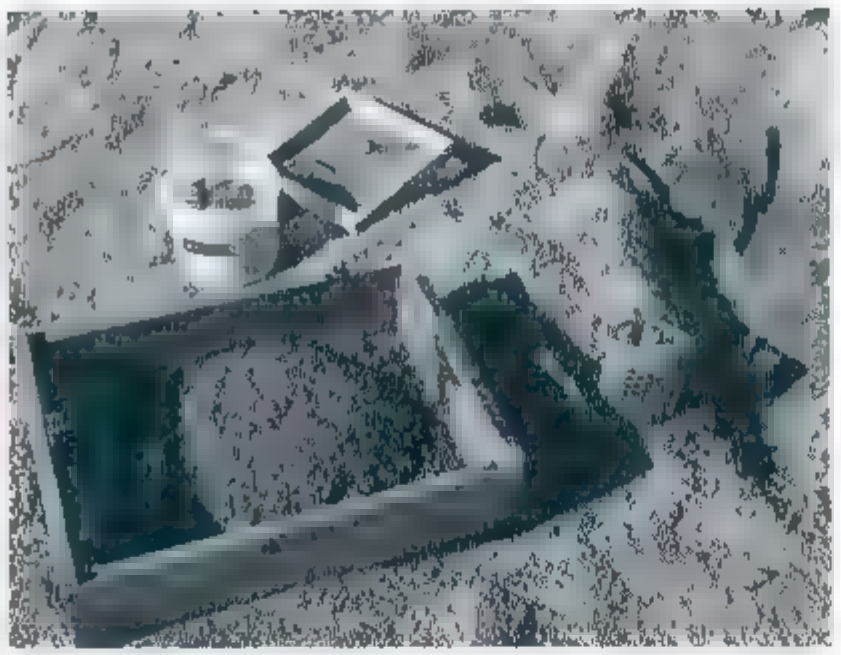
I worked for another half hour or so before taking a break. This is when I hit pay dirt! After carefully examining one of the screen loads, I found my very first topaz crystal. I excitedly held it up to the sunlight. It's beautiful! It's not what one would call top-notch gem grade, but is beautiful just the same. It has a grayish-brown layer running across one third of the crystal, and even though it's irregular, it has something of the typical topaz crystal configuration. It's short and stubby, and the main body of the stone is water clear. As I hold it up to artificial light, its natural facets sparkle. By examining the crystal, I found that it actually hadn't traveled far from its origin, due to the sharp edges on the stone.

I was getting tired from all the exertion, so it was time to relax before lunch. This is when I decided to investigate the surroundings a bit. I walked slowly upstream, all the while studying the ground around me. By chance, I just might find something worthwhile.

I have no idea of the property's size. I do know that it covers a tremendous acreage. The map given me at the store shows Topaz Gulch, which I later investigated, and Honey Creek, plus the roads and buildings on the property. Honey Creek meanders for quite a way upstream to a fence line that dissects the property.

As I walked slowly upstream, I came across a huge outcrop of red granite boulders and bedrock. Although there evidently isn't a great deal of water movement, I suspect that could be the origin of the topaz deposit farther downstream. At one time or another, these rocks were not only washed clean, but partially disintegrated, releasing any topazes held captive during the millennia.

After a late lunch in the camper, I returned to do more screening. The hole



I used a large screen to sift the gravel in search of topaz at Honey Creek.

was caved in a bit from water movement, and I had to reach down deeper to get a shovelful now. I could've used a long-handled shovel, but I had to make do with what I had.

In one of the screen loads, I discovered my second topaz! I excitedly held it up to the sun, but it's too dense to see any light through it. It's a beautiful, very dark grayish purple stone. I don't know if it will make a decent gemstone, due to this opaque nature, but I'll keep it just the same.

The thought crossed my mind that it would be not only interesting but, no doubt, lucrative to have access to a small pay loader and dig down to bedrock in the deposit. This is where the crystals have come to rest. With my short-handled shovel, I never was able to dig any deeper than 3 feet. The only solid objects I reached with the blade were boulders. Some were too heavy to lift out of the hole, so I shoved them aside.

As the sun began to dip down near the western horizon, it was time to head back to the camper. I was tired, but happy with the thought that I had actually found another keeper. It shows some water wear in its rounded-off edges, and it has no distinct shape. It's light gray and translucent, with a number of creamy white inclusions running through it. I was satisfied that I had found three rather good topaz crystals that day, and I was optimistic about the morning to come. It was getting late and I was hungry, so I walked back to camp.

When I arrived at the camper, the winter sun was already dipping below the western tree line. I had done a fair amount of work and enjoyed some luck, and the time spent here was like a tonic. I still had several hours in the morning in which to finish my allotted time.

Shortly after breakfast next morning, I decided to spend my remaining hours searching the surface. There was still a great amount of ground that I hadn't had a chance to examine. I realized that there was no way that I could possibly search even a small fraction of this topaz field, but I was going to give it my best shot. So I set out, searching as much of the surface of the creek bed as I could. My wandering eventually took me over to Topaz Gulch, north of Honey Creek, where I went upstream for a good distance before coming to the fence.

I had experienced excellent weather ever since I had left Betty Carol in Florida. This day was also beautiful, with only a few fluffy clouds drifting by in a deep blue sky. It was shirt-sleeve weather and I was enjoying this respite from winter immensely.

It was getting close to the end of my 24 hours and I was thinking about my time at the site when something suddenly caught my attention. It was a bright flash of sunlight reflecting off something behind me. I turned, reached down, and picked up a magnificent, glistening, water-clear topaz crystal. It's all of 6 carats in size and has the shape of a tiny ice cube: square and cleaved off at one end in a perfect 90-degree angle. When turned at a certain angle, the light refraction causes the color bands of the spectrum, predominantly blue, to appear. It's beautiful! I plan on making a wire-wrap cage for it and leaving it in its natural form, suspended from a chain.

During my stay at Honey Creek, no one else came by. I thought how great it would be to spend a few more days here. I'm almost certain that I would find more topaz crystals. But my honeymoon/vacation was coming to a close and more pressing matters awaited me back in Minnesota. I'd be home before Betty Carol and her family, who were still on the Caribbean cruise.

I returned the key to the store in Mason and was on my way north. It had been a marvelous adventure and I had accomplished what I set out to do. I finally had four Texas topaz crystals in my possession. It was a good feeling.

If you plan on visiting Mason County to do some topaz mining, make certain that you don't make the same mistake I did the year before, when I arrived in Mason County during deer hunting season. No one is allowed in the topaz fields during that time.

For more information, contact Garner Seaquist Ranch, P.O. Box 35, Mason, TX 76856, (325) 347-5713. If you're in the area, make it a point to visit the Chamber of Commerce in Mason. They are very helpful.

ROCK SCIENCE

by Steve Voynick

Polymerization, Dessication ... and Amber

Amber, one of the most beautiful and unusual of all fossils, is fossilized tree resin, a definition that is valid only if we expand the usual meaning of the word "fossilized." While most fossils are created through the physical processes of mineral replacement or molded impressions, amber forms through the entirely different chemical process of molecular polymerization.

Because it lacks a definite chemical composition and an ordered crystal structure, amber is not a mineral. Technically, it is an organic nonmineral, a natural substance of organic origin that satisfies neither the definition of a mineral nor that of a mineraloid (a mineralike material such as opal that lacks a crystalline structure).

Chemically, amber is an oxygenated hydrocarbon of variable composition with an amorphous structure. It consists roughly of 80 percent carbon, 10 percent oxygen, 9 percent hydrogen, and traces of other elements such as sulfur and phosphorus.

Amber originates as tree resin, a general term for a large group of solid (or semisolid) organic hydrocarbon materials of vegetable origin. Various tree species exude resins primarily as a defense mechanism against fungal or insect attack. Although resins vary widely in chemical composition, color, and fragrance, all are mixtures of organic acids, sugars, esters, and terpenes, the last a group of hydrocarbon compounds that are the key to the fossilization of amber.

Newly exuded, soft, tacky resin begins the long process of fossilization almost immediately when its most volatile terpenes begin to evaporate. Next, the less-volatile terpenes start to slowly polymerize, linking together to form long molecular chains. Polymerization homogenizes and hardens the resin and loosely organizes its molecular structure. The presence of atmospheric oxygen then prevents any further fossilization. The surface of the resin oxidizes, cracks, and sloughs off as fine particles, leading quickly to complete disintegration of the entire resin mass.

To become amber, further fossilization must occur within an anaerobic environment. Buried long-term in conditions that are devoid of free oxygen, resin transforms first to copal, a subfossil or partially polymerized resin with an amberlike color and general appearance. Copal, which is sometimes sold as amber, has poor chemical stability because it is only partially polymerized. Over time, copal's remaining volatile terpenes will continue to evaporate, "crazing" its surface into a network of deep cracks.

But if copal remains anaerobically buried for millions of years, its terpenes continue to either evaporate or polymerize. Fossilization can then progress, and the original resin will eventually attain chemical stability in the form of amber.

The oldest fossil resins are about 320 million years old. Because of the type of resins exuded by primitive trees, these early fossil resins occur only as tiny grains that differ chemically and physically from amber derived from resins exuded by more highly developed trees. The first true ambers originated some 230 million years ago, but only during the Cretaceous Period (65 million to 135 million years ago) did resin-exuding trees become sufficiently abundant to produce the resin necessary for the fossilization of large quantities of amber.

The preservation of amber inclusions takes place by yet another process, desiccation. Amber inclusions can consist of anything from flora (pollen, seeds, flowers, spores, and wood and leaf fragments) to fauna (insects, spiders, scorpions, bird feathers, and even small lizards). Because of its tackiness, newly exuded tree resin is a natural trap for such materials. For preservation to occur, however, resin must be continuously exuded in layers to cover the trapped materials, thus allowing the resin's hygroscopic sugars to begin drawing away water to completely desiccate them. Should this resin eventually become amber, the degree of detail in the desiccated inclusions, from internal and external organs to muscle fibers and individual cells, is remarkable.

Polymerization and desiccation aren't usually thought of as fossilization processes, but that is exactly what they are. And the proof is in a beautiful piece of transparent, golden amber containing a 100 million-year-old insect that looks like it was alive only yesterday.

COLLECTING ROCKS FROM SPACE

Tips for Beginning Collectors

Story and Photos by Mark Mathosian

The "thumbprints" on this 4.7-kilo Argentina meteorite are a telltale sign of an iron meteorite. I call it Campo del Cielo (Iron from Heaven).

If you are new to collecting meteorites, consider yourself lucky. Experienced meteorite collectors and sellers are willing to share their knowledge with you. And there are plenty of meteorites to go around; 20,000 or more reach the Earth each year. While most meteorites go undetected or land in an ocean, many are collected and offered for sale in a well-established secondary market. Here is information to help you tap into that market and start building your collection of stones from space.

WHAT ARE METEORITES?

Meteorites are generally defined as natural objects of extraterrestrial origin (meteoroids) that survive passage through the atmosphere and hit the ground. They are from our solar system and represent the remains of a meteor or "shooting star" that flashes through our atmosphere at estimated speeds of 25,000 to 56,000 miles per hour. Most earthbound meteoroids come from asteroids shattered by impact with other asteroids. Others represent pieces of planets like Mars, planetary satellites like our moon, and presumably comets.

Of the thousands of meteorite falls each year, fewer than 10 are actually observed. These meteorites are recovered and become specimens for collection, scientific study, and museum specimens.

A meteorite found on the ground after a meteorite event has been witnessed is called a "fall." Those found by chance are called "finds." Each fragment from a meteorite shower is called an "individual." The geographic area where meteorites are found is called a "strewn field."

Meteorites fall at random and are found all over the world. Many fall into oceans and are never recovered. Interestingly, the chances of being hit by a meteorite are extremely small. It is believed that only 60 people have been struck by a meteorite in the last 3,000 years. That equates to one person every 50 years.

This is a slice of Homestead, a chondrite meteorite that landed near Homestead, Iowa, in 1875.

When meteorites are discovered, or observed falling, they are usually named after a town or large geographic landmark closest to where they landed. For example, a huge meteorite that crashed in Siberia, Russia on Feb. 12, 1947 was named after the prominent local mountain range Sikhote-Alin. Farmers working on the mountain watched in amazement as a huge fireball roared through the sky and crashed into the ground. Sikhote-Alin made a crater 87 feet in diameter and 20 feet deep. Individuals from the Sikhote-Alin fall are readily available in today's market place at affordable prices.

Another example is the Estherville meteorite, which hit the to Earth three miles north of Estherville, Iowa, on May 10, 1879. The Estherville meteorite burst apart as it neared the Earth and was seen breaking into three large pieces weighing 431, 151 and 106 pounds. Estherville meteorites are also available from a variety of sources.

By now you are probably wondering what makes a meteorite different from rocks and stones found on Earth. The fact is, in some instances they are not much different. For example, some meteorites resemble volcanic rocks. Others contain alloys like iron and nickel. Iron and nickel meteorites are believed to be similar to the materials found in the Earth's core.

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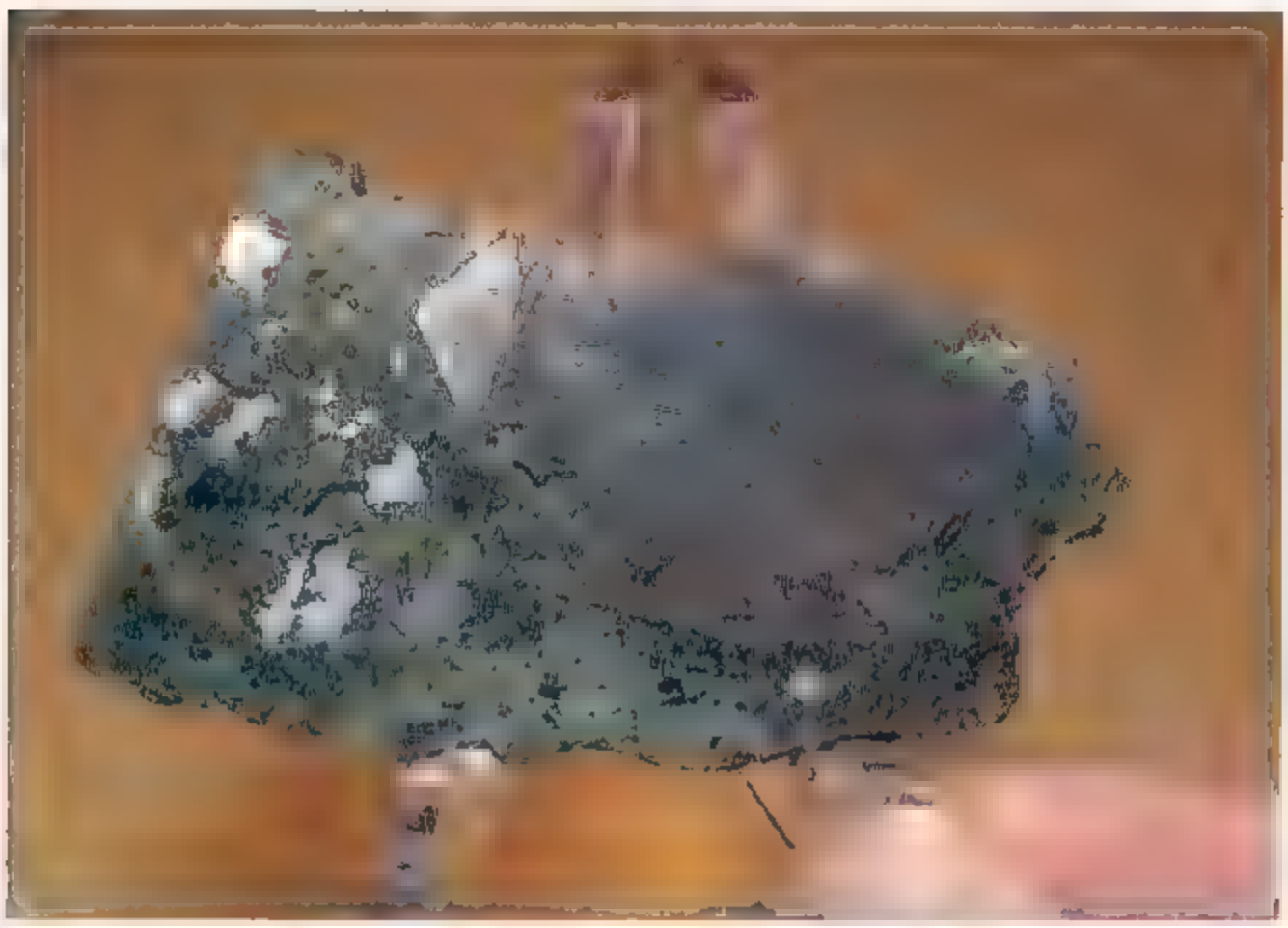


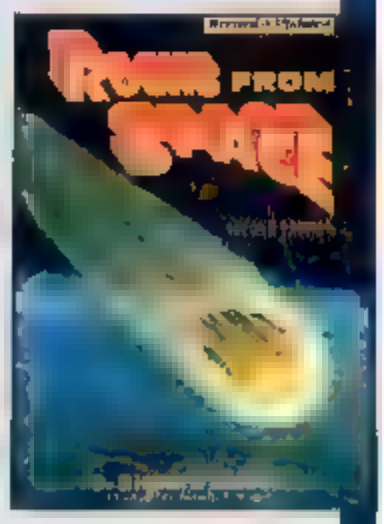
The Estherville (Iowa) meteorite is composed of iron, nickel, phosphorous, sulfur, and some unknown alien metal

MORE ABOUT METEORITES

Before spending money on meteorites or attempting a field search, read one or more of these excellent books or magazines. All were written by experienced meteorite collectors and/or meteorite experts. After doing your homework, you will be ready to start shopping.

***The Art of Collecting Meteorites*, by Kevin Kichinka (Bookmasters, 2005), $21.95.** Kichinka has been collecting and writing and lecturing about meteorites for years. His book is easy to read and provides very practical information and advice. He briefly covers all subjects you need to know, from where to locate established dealers to getting started finding meteorites yourself. Kichinka also provides good tips on storing, maintaining and displaying your collection. Appendixes at the back of the book provide resources on where to have meteorites examined for authenticity and a list of informative meteorite-related Web sites. You can order this book from www.theartofcollectingmeteorites.com.

***Rocks from Space*, by O. Richard Norton (Mountain Press Publishing Co., 1998), $32.** In its 2nd edition, this book is considered a bible of meteorite collecting. Norton explains what you need to know about "shooting stars, meteor showers, and fireballs." If you enjoy history, you will like this one. Norton takes you back as early as the 1400s to the oldest witnessed fall of a meteorite. You will learn how to recognize a meteorite, including chondrite, achondrite, iron, and stony-iron types. He covers America's great Meteorite Crater in Arizona located near the meandering Canyon Diablo, a popular tourist attraction. *Rocks from Space* should be on every meteorite collector's library shelf.



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Collecting Rocks from Space *from page 81*

This 550-gram fragment of the Sihote-Alin meteorite, which fell to earth in Siberia on Feb. 12, 1947, is one of my favorites.

Some meteorites are very different from Earth rocks and contain materials not found on Earth. The Estherville meteorite is a good example. This space stone is composed of iron, nickel, phosphorous, sulfur, and a metal not found on Earth. Because it contains an alien metal, it is even more attractive to collectors.

Scientists believe some meteorites contain the primitive materials from which our solar system was made. Therefore, meteorites represent some of the scarcest material on Earth and are held in high regard along with other rare and highly valuable objects such as gold. Because of their scarcity and primordial origins, meteorites have been dubbed "the poor man's space probe."

TYPES OF METEORITES

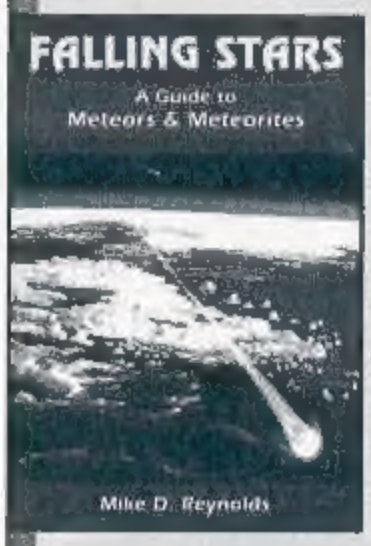
Without getting too technical, meteorites can be broken down into three main types: stone, stony-iron and iron.

Stone meteorites are mainly composed of minerals similar to those found in Earth rocks. However, the proportions of these minerals are different from those in Earth rocks. It is believed that rocks in the Earth's deep interior may closely resemble stone meteorites. About 90 percent of observed meteorite falls are of the stone type and most are discovered in Middle Eastern deserts or the Antarctica. Dark rocks from space stand out dramatically against the vastness of desert sands and the white ice cover of Antarctica. Stone meteorites are referred to as "common chondrites." Chondrites appear to be unchanged since their formation around 4.5 billion years ago. As a point of reference, our sun is believed to be roughly 4.5 billion years old.

More About Meteorites *from page 81*

***The Cambridge Encyclopedia of Meteorites*, by O. Richard Norton (Cambridge University Press, 2002), $34.65.** This is another great book by Norton, but it's much more technical than *Rocks from Space*. The encyclopedia is a hard-bound coffee-table book that goes into extreme detail about the origins of meteorites and their internal structure and classifications. If you want to become an expert in meteorites, read this one. Just be warned: The encyclopedia is more like a college text than a book for hobbyists. A highlight of the book is its fantastic collection of meteorite photographs. The color photos are worth the price of the book.

***Falling Stars: A Guide to Meteors and Meteorites*, by Mike D. Reynolds (Stackpole Books, 2001), $12.95.** *Falling Stars* is a quick read loaded with information. You will get an instant education on meteor and meteorite origins, meteor watching, meteor showers, meteorite falls and finds, craters, classifications, collecting and preserving meteorites, and organizations, dealers and museums. Even though it is a small paperback, *Falling Stars* is filled with nice black-and-white photos of meteorites, craters, and related subjects. There is also a chapter on tektites, fused glassy material often found near meteorite impacts. Some people prefer to collect tektites in addition to or instead of meteorites.



***Meteors, Meteorites and Meteoroids*, by Ray Spangenburg and Kit Moser (Franklin Watts, 2002), $14.95.** This is another helpful paperback loaded with educational information about meteorites for beginning collectors. Mezteoroids, comets, meteor showers, and famous meteorite finds and falls are discussed. There is also a nice introduction to meteorites believed to be from Mars and a mind-challenging chapter on whether meteorites are the seeds of life for planets such as Earth.

***Meteorite* magazine: The International Quarterly of Meteorites and Meteorite Science (published by Joel Schiff, Pallasite Press, Takapuna, Auckland, New Zealand), $30 per year.** I would be remiss if I didn't tell you about this magazine dedicated to meteorite enthusiasts around the world. It has up-to-date information about meteorites, from the latest finds and falls around the world to stories about exotic meteorite expeditions. It also contains advertisements from reputable meteorite sellers. *Meteorite* magazine nicely blends technical and general information into one publication. Over the years, I have learned much from this magazine. Subscribe at http://meteoritemag.uark.edu/.

***Astronomy* magazine: Observing, telescopes, origin and fate of the Cosmos (Kalmbach Publishing Co., Waukesha, WI), $42.95 per year.** Expand your knowledge of meteorites into the heavens with this popular astronomy publication. "Clear, jargon-free articles" bring the science of space to the hobbyist's level. Sample article titles from the August 2006 special meteorite issue are "How to start your meteorite collection," "The great interplanetary rock swap," "Rock-metal fusion," and "Name that rock." Subscribe online at www.astronomy.com and take advantage of online extras like the Intro to Astronomy.

Stony-iron meteorites contain some metal, about 23 percent nickel-iron and varying amounts of other minerals. They account for about 1 percent of discovered meteorites. Achondrites, a type of stony meteorite, are thought to be the product of melting asteroids or planets that had compositions like chondrites. Many achondrites are chemically similar to basalts, the common type of lava produced by volcanoes on Earth.

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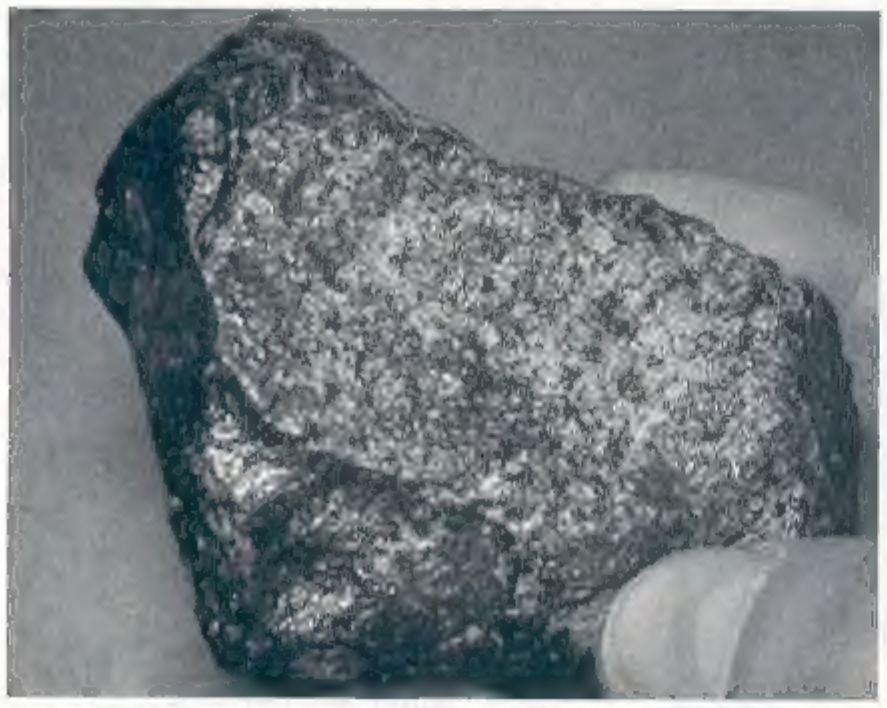


A 231-gram stone meteorite from the Sahara Desert is magnetic and a nice specimen of a relatively new fall.

Mesosiderites and pallasites are two types of stony-irons. Mesosiderites are broken fragments of mantle rock and nickel-iron that were fused together by impact with another body. Pallasites have gemstonelike qualities. They contain a blend of crystalline olivine and random patterns of nickel-iron. Pallasites are attractive and in demand by collectors. When you see one, you will want it in your collection. Stony-irons are rarer than common chondrites and often demand a premium price. When observed under a light these multifaceted space stones are truly beautiful.

Iron meteorites are the cores of planets and asteroids. At one time, iron meteorites were completely molten and inside the core of asteroids. Irons represent the largest meteorites found on Earth and are made of solid metal, 98 percent nickel-iron, with slight traces of other minerals. Individual irons often resemble the asteroids and meteors portrayed in science fiction movies. In fact, it is the iron meteorite that comes to mind when most people visualize a meteor or asteroid. Irons are often cut into slices so their interior can be polished and displayed. Put a magnet to polished iron and you will surely keep someone's attention.

Meteorites are scientifically divided into many categories and classifications depending on their makeup. You can learn more about them by reading some of the books referenced in this article.

RECOGNIZING A METEORITE

Meteorites tend to be heavier than terrestrial rocks of a similar size, typically three to four times heavier. They are often gray, black, or dark brown in color. Fresh meteorites are gray or black; weathered space stones are dark brown or may appear rusty. The black or gray color of a meteorite's outer crust is caused by the heat generated as it enters the Earth's atmosphere. This is referred to as "fusion crust."

Some meteorites also display minute "flow lines." Flow lines occur where melted material flowed off of its surface as it powered its way through the friction and heat caused by Earth's atmosphere. Meteorites with flow lines make a nice addition to any collection because they show physical evidence of the stones' violent journey from outer space to the ground where they landed.

If you are searching for meteorites on the ground, investigate rocks that stand out because they look different from the rocks around them. Even if it looks different from the surrounding rocks, it may still look like an ordinary stone. Don't let its ordinary appearance fool you. If it stands out from the others and is heavy, it may be a meteorite.

If you intend to search for meteorites in the field, invest in a good metal detector and a heavy magnet. Most meteorites attract magnets. If you discover a heavy rock and your magnet is attracted to it, it is likely a meteorite. Ninety percent of meteorites, even stony ones, are slightly attracted to magnets.

Another dead giveaway is the shape of meteorites. These extraterrestrial visitors are shaped by the forces they encounter when they blast through the Earth's atmosphere. The surface of a meteorite will likely be smooth with rounded corners. As mentioned above, it may also show flow lines where its surface was heated during its arrival. A meteorite might also have depressions and smooth pits referred to as "thumbprints." Thumbprints are common on iron meteorites. They look as if someone pushed their thumbs into soft clay to make the indentations. This is usually a sure sign you found a meteorite.

Another way to verify whether a stone is a meteorite is to slice off a piece and have it examined by an expert or experienced collector. Stony meteorites typically have silvery flecks dispersed in their mass. Iron meteorites will appear as a solid piece of metal, very chromelike in appearance. Buff one, and it will shine beautifully.

The more meteorites you look at, the better you will be at identifying one when you see it. Read books and magazines and visit museums that have meteorite collections. Seeing and handling samples firsthand will give you a good feel for what to look for.

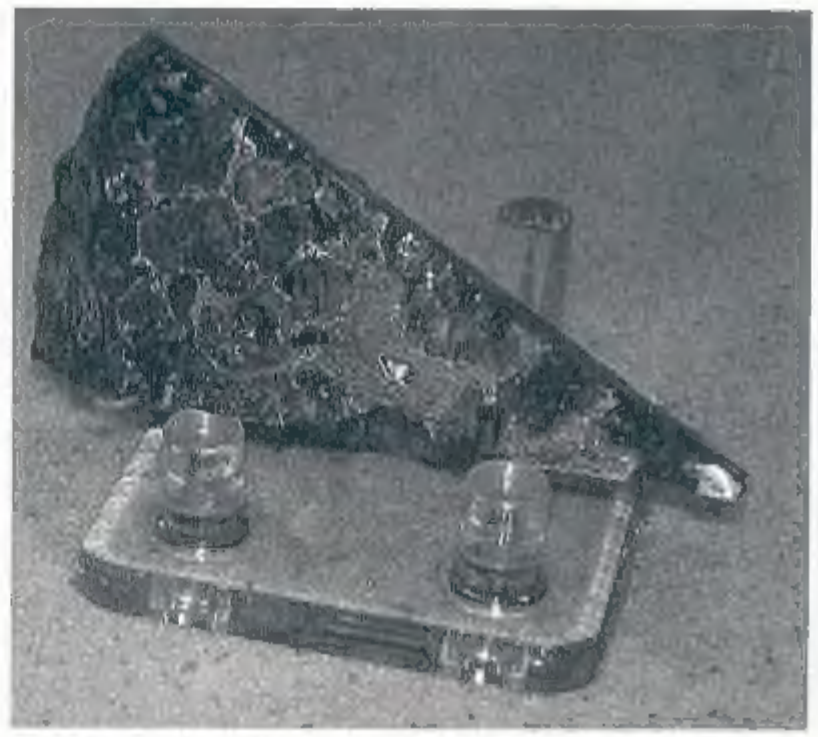
If you don't have access to a meteor field, you can buy specimens. You will find that many reputable dealers sell meteorites over the Internet and at rock and gem shows. You'll also find the names of reputable sellers in meteorite books and magazines.

If you shop on eBay or another online auction site, be extremely careful. Meteorite "wrongs"—stones that look like meteorites—have occasionally been offered for sale. While this doesn't happen often, you don't want to get stuck with a meteorite wrong.

As a guideline, consider buying meteorites from eBay sellers who also have a Web site or a "brick and mortar" store. Become familiar with weights and sizes; meteorites are usually sold by grams. They tend to look bigger on a computer screen than they actually are. You don't want to be disappointed when your meteorite arrives in the mail and it isn't what you thought it would be.

Finally, don't be afraid to purchase from meteorite sellers located outside the United States. I have purchased several nice specimens from European sellers. Meteorite collecting is a worldwide hobby.

Mark Mathosian has been collecting meteorites for five years. He is an amateur astronomer who spends his evenings digitally photographing the moon and planets. He can be reached at mmathosian@comcast.net.



This sample of the Brahin (USSR) pallasite meteorite is made of a nickel and iron matrix with yellow-green crystals.

On the Rocks

Old Mines of Mexico

Living in Arizona gives a rockhound plenty of opportunities to go to south and investigate old mines in Mexico, a country rich in natural resources. Long before the Spaniards dominated the country, mining was ongoing. The invaders intensified the search for minerals, primarily gold and silver. This opened new mining districts, some of which are still working, producing useful metals and yielding some quite remarkable minerals. Other mines are closed, having reached *borrasca,* or near-barren rock.

The mine at San Pedro Corallitas is one such old mine. No longer being worked for metal ores, this deep mine is held in high esteem by collectors because of the mimetite it produced after closing.

When gold and silver prices rise, these Mexican mines may reopen. Meantime, plenty of unemployed miners and Anglos get into these old workings and scratch around for specimens they can sell. Trips into mining camps often give a collector a chance to buy some pretty nice minerals.

My one trip into the mine at San Pedro Corallitas was to see where the bright-yellow botryoidal mimetite occurred which Benny Fenn had mined out. Benny is an amazing fellow. He is a top-notch dealer in Mexican minerals and he has brought to market some really amazing batches of specimens, including the mimetites, Los Lamentos wulfenites, moonstones, legrandites, and more.

The San Pedro Corralitas discovery was made when Benny was checking out the old mine for specimens. He came across a large fault gouge filled with granular cerussite. He recognized its value as ore and set up a mining operation, extracting over 7 tons of the crumbly lead carbonate.

That wasn't the end of the story. While digging out the cerussite, he exposed the walls of a huge opening lined with yellow botryoidal memetite. The first batch he mined was hauled to Tucson and sold to wholesale mineral dealer Susie Davis. The material was a bit friable, with the rounded knobs separating easily. The color ranged from very pale tannish yellow to good yellow. After preparing the material, Susie was able to sell the mimetite for $3.75 a pound! I know that was the asking price because Susie called me about the find and I drove down to Tucson and bought some.

Once Bennny had collected the specimens on the walls, he followed an open seam and was able to recover dozens of boxes of brilliant botryoidal mimetite that was far superior to the earlier batch. This material was lustrous, much more solid, and brilliant yellow. Benny hauled the load to Davis Minerals in Tucson and Susie called me again. This time, the mimetite was sold for $5.75 a pound! That sounds almost too good to be true compared to today's prices.

My first visit to the silver mine at Naica was to see the minerals they had on display, mainly large selenites. The geologists were in the habit of collecting specimens as they worked underground. Sometimes, you could buy a batch at the office. The prices were never stiff and the selenites were usually fine textbook crystals, water clear and quite attractive.

My second visit to Naica came years later after the discovery of an amazing cavern on the 2,500-foot level. I got to know a photographer from Tucson who had seen the cavern, and he agreed to accompany us to Naica. Benny Fenn, his son Benny Jr., and my son Evan were in the group.

I had seen some of the photographs, but when we climbed into what has since become known as Caverna de los Crystales

Bill and Chris Panczner and a miner enjoy the amazing selenite growths, which have since been destroyed, in the Caverna de Santa Barbara.

Gigantis, I was stunned. There in front of me were free-standing selenite crystals slanting off in all directions. The smaller crystals were a few feet long, but the larger ones reached from floor to ceiling and measured nearly 50 feet long! The crystals were so fat—about 4 feet in diameter—that two of us reaching around the crystals could not touch hands. The floor was littered with huge crystals and the walls were coated with crystallized selenite. One free-standing, perfect monoclinic crystal measured over 6 feet across!

The cavern extended as far as you could see and it would have been a bigger thrill if we could have explored deep into this forest of selenites. That was not possible because the cavern temperature reached 150 degrees F and the humidity was close to 100 percent. If you have ever opened an oven door when a roast is being cooked, you know how the cavern felt.

I could only stick it out in the cavern for about five minutes. After that, I dashed out into the cool, 95-degree tunnel! After cooling down some, I could go back in for another five minutes. I dashed in and out a half-dozen times, each time trying to grab a useful photo. The visit to Caverna de los Crystales Gigantes was an experience I can't forget, and I was lucky enough to repeat it a year later.

The second trip to Naica was, again, with Benny Fenn. This time, we took our wives, Carol and Elva, to enjoy this remarkable sight. During this trip, our miner guide was kind enough to also take us into another selenite cavern at Naica. This crystal treasure-house is fairly well known and written up as the Cave of Swords.

Discovered in 1921, the Cave of Swords was largely ignored for years. Miners could wander in and break off a crystal or two. Even the local doctor was able to gather specimens for sale, using the money to help injured miners. Finally, the mine operators realized they had a treasure. They closed the cavern off with a steel door, built steps up to the entrance, and put in a wooden walkway so guests could wander deep into the cavern, admiring tens of thousands of selenite crystals jutting from the floor and walls. The Naica caverns are certainly the best I've ever been in, but they were not the only ones.

In 1978, when I was on the Board of Governors of the Arizona-Sonora Desert Museum, then museum curator Bill Panczner and I organized a one-month collecting trip into Mexico. Bill's son Chris and my son Evan went with us. We

by Bob Jones

went to Durango and collected at the huge Cerro de Mercado iron mine, famous for its single, yellow apatite crystals. We also collected at San Martin and Fresnillo, two very productive silver mines.

The highlight of this trip was time spent at Santa Eulalia, where a number of mines are located. Bill had gotten word that the Buena Tierra miners had broken into a selenite cave, and we were determined to get into that natural wonder. However, when we talked to the mine superintendent, he denied the cave even existed!

After some earnest conversation, the superintendent agreed to take us underground the next day. We arrived the next morning and were escorted down a new incline being put in to reach a deep ore body. About 400 meters in, we came upon a huge mine-timber wall with a small, square door in it. The superintendent unlocked the door and invited us to crawl through.

Evan went in first and I started in second. As I was crawling through the small opening, I heard Evan say, "Dad, this is like science fiction!" Once I got inside, I agreed with him.

We were looking at a cavern some 120 meters deep, 15 meters high, and 20 meters wide. The walls were covered with small monoclinic selenite crystals, as was the floor. Luckily, the temperature was very mild, so we were able to stay for more than a hour.

The highlight of this cavern, named Caverna de Santa Barbara, was 7-foot-long selenites spraying off the floor in clusters that spanned 15 feet. Every form of selenite was there: huge fishtail twins, small monoclinic singles, blades exceeding a foot in length, ram's horn clusters, helectites, and sheetlike white curtains of selenite. Years later, we found out that, because of heavy blasting of the ore body a couple of levels below the cavern, all the free-standing crystals cleaved off and the cavern was destroyed!

Yet another selenite cave found in Mexico has been preserved. Near the town of Aldama, Chihuahua, a hole in the ground revealed a small cave that was nearly filled with water. Looking down through the clear water, you could see a jungle of selenite crystals. Benny Fenn, that tireless digger of minerals, brought in a diesel engine to run a pump and drain enough of the water so he could collect the crystals. He gathered enough crystals to re-create the cavern, called Caverna de Velas (Cave of the Candles), in the Arizona Sonora Desert Museum.

On yet another trip, I visited the mines at San Martin and Fresnillo in Durango. My goal in going to San Martin was to get permission to go underground and seek out stibnite pockets. The mine superintendent was kind enough to escort my group underground.

It was an amazing journey. We went down to the 2,000-foot level, a distance measured from the peak of the mountain in which the mine was located. As we walked along watching the cut-and- fill mining operation, we finally spotted some small fragments of stibnite on the tunnel floor.

This is a superb example of the yellow botryoidal mimetite mined by Benny Fenn at San Pedro Corralitas, Mexico.

Looking up, we spotted an open vug about 20 feet up the wall. The superintendent was kind enough to get a front loader and instruct the driver to lift us up in his huge bucket to collect stibnites.

We let Evan and Chris go up first, but when they passed down a couple of nice specimens, we kicked them out of the bucket and Bill and I were lifted up to collect. What we collected was for the museum, but we were allowed to keep one specimen each, a nice reward for our hard work.

We were preparing to leave on a trolleylike vehicle that was also taking the working crew to the surface. We had to pack the stibnites for transport, but the only materials available were oily papers and empty dynamite boxes. We packed the stibite carefully and climbed aboard with our load. Immediately, the miners got off the trolley and started to walk up the incline! After some confusion, it finally dawned on us that the miners were refusing to ride with what they thought was leftover dynamite. We showed them the stibnites in the dynamite boxes, and a comfortable ride to the surface was had by all!

Another trip Benny and I took was to see Benny's feldspar gem mine. He had found the site while riding a four-wheel offroad vehicle in the open desert of Chihuahua. The gem mine is a series of volcanic flows, one of which is loaded with gem feldspar phenocrysts. When molten lava slowly cools, discrete mineral crystals have a chance to begin forming—in this case, crystals of yellow labradorite. Some of the misshapen crystals are 2 inches long, while most are under ½ inch, but the flow is loaded with crystals. Weathering had been working on the flow for centuries and the ground around the small volcanic hill was covered with bright-yellow crystals. Some were still attached to lava, while others were completely loose.

When Benny found the site, he collected crystals and had some of them faceted. They cleaned up nicely and were showy and sharp. Feldspar has a Mohs hardness around 6, and these lovely, delicately colored crystals were very attractive when cut.

Our trip into the site required a long and very bumpy ride over the open desert. My wife, Carol, was with us, and she was anxious to collect a few crystals to try faceting someday. As we approached the gem area, I could not find any features that distinguished it from the surrounding hills. Yet, Benny had found it by tracing float he found in a shallow creek bed.

We began gathering crystals off the desert floor, and within an hour Carol and I both had enough to fill two large plastic bags. Enough was enough and we left, grateful to have had a chance to enjoy such easy pickings!

From all this, I'm sure you get the feeling that Benny Fenn is not only a top-notch dealer in Mexican minerals, but a really important contributor to the joy of mineral collecting. I look forward to more trips into Mexico with Benny, a firm friend and a swell fellow!